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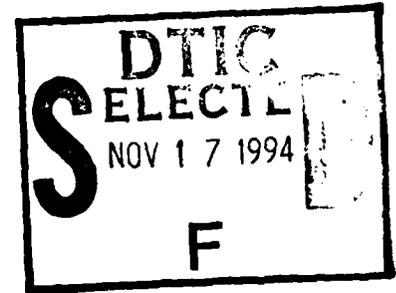


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DOT/FAA/NR-94-1
DOT-VNTSC-FAA-94-10

Office of Program Director
for Surveillance
Washington, DC 20591

Recommendation on Transition from Primary/Secondary Radar to Secondary-Only Radar Capability



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Final Report
October 1994

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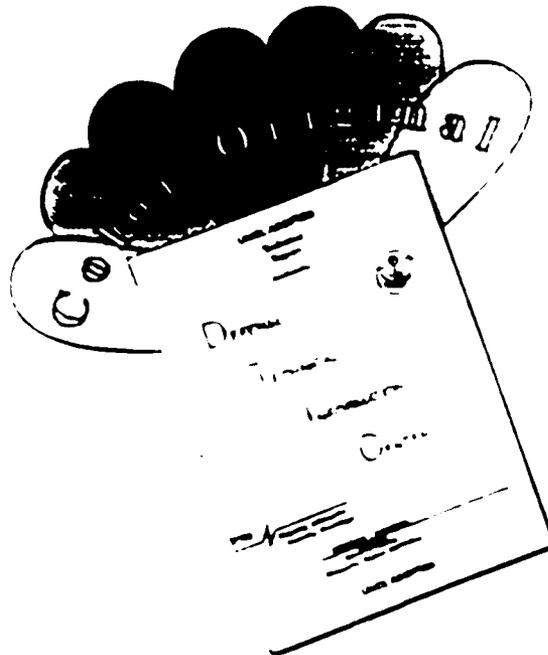
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1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE October 1994	3. REPORT TYPE AND DATES COVERED Final Report Sept. 1993 - March 1994	
4. TITLE AND SUBTITLE Recommendation on Transition from Primary/Secondary Radar to Secondary-Only Radar Capability		5. FUNDING NUMBERS FA4M5/A4031	
6. AUTHOR(S) Janis Vilcans ¹ , Richard J. Lay ²			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) ¹ U.S. Department of Transportation Research and Special Programs Administration John A. Volpe National Transportation Systems Center Cambridge, MA 02142-1093		8. PERFORMING ORGANIZATION REPORT NUMBER DOT-VNTSC-FAA-94-10	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Federal Aviation Administration Office of Program Director for Surveillance Washington, DC 20591		10. SPONSORING/MONITORING AGENCY REPORT NUMBER DOT\FAA\NR-94-1	
11. SUPPLEMENTARY NOTES ² U.S. Department of Transportation Federal Aviation Administration Program Office for En Route Radar Washington, DC 20591			
12a. DISTRIBUTION/AVAILABILITY STATEMENT This document is available to the public through the National Technical Information Service, Springfield, VA 22161		12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) This recommendation has been prepared to support the FAA decision to deactivate primary long-range radars and presents a transition strategy and implementation plan for the transformation of the existing primary/secondary en route radar system to a beacon-only system by the year 2002. The estimated cost associated with this transition is \$2.1 billion, but the cost directly related to the decision is approximately \$138.6 million. Thus, the potential saving of approximately \$1.4 billion associated with LRR replacement results in a benefit-to-cost ratio greater than 10. It is therefore recommended that the decision to deactivate the LRR be implemented as rapidly as possible in order to minimize costs necessary to sustain and maintain the existing system; that an orderly transition be accomplished; and that the transition to the beacon-only capability be adopted on a center-by-center basis. It is also recommended that the goal of an en route beacon system, comprising stand-alone beacon radars and backed up with an automatic dependent surveillance (ADS) system be established, but achievement of this goal should not delay implementation of the deactivation decision.			
14. SUBJECT TERMS Primary Radar, Mode S, CONUS Coverage, NEXRAD Coverage, Automatic Dependent Surveillance (ADS), ATC Radar Beacon System (ATCRBS)		15. NUMBER OF PAGES 172	16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT Unlimited

PREFACE

The work described in this report was performed under Project Plan Agreement FA-4M5 for the Federal Aviation Administration (FAA), Program Office for En Route Radar. The sponsor of the project, Richard J. Lay, ANR-400, directed the work study effort.

The work was performed by the U. S. Department of Transportation/Research and Special Programs Administration/Volpe National Transportation Systems Center, Surveillance and Sensors Division. This report, in support of the FAA decision to deactivate primary long-range radars, presents a transition strategy and an implementation plan for the transformation of the existing primary/secondary en route radar system to a beacon-only system by the year 2002.

The authors wish to thank Edmund J. Koenke, Sc. D., for his contribution to the preparation of the report, implementation plan, and modernization programs analysis, and for participating in reviews.

The authors also wish to thank Michael J. Polchert, ANR-800, for his technical contributions, for conducting the technical reviews and approval of the report. Thanks also to Edward Spitzer, Chief, Surveillance and Sensors Division, for his review of the report and valuable suggestions.

Especially grateful acknowledgments go to the following individuals for their technical contributions in reviewing the report and making valuable improvements:

ANR-400/HTI	Robert Wunderlich	ASM-140	Wendie Chapman
ANR-400/HTI	Micky Finn	ASM-147	Mark Katzen
ANR-401	Arthur Levy	ATR-111	Ivonne Toledo
ANR-402	Olivia L. Stevenson	ATR-113	Robert Paul
ANR-700	James Moe	AOS-230	Robert Taylor
ANR-800	Dennis Kolb	ASE-300	Doug Hodgkins
ANR-800	Teddy R. Boatright	ANM-462	George Johnston
ANR-800	Michael Huffman	ANM-462	Darrell Carlson

SRC	Paul D. Abramson, Sc. D.
TASC	Alan G. Cameron
TASC	Dr. E. Michael Geyer

Special thanks go to Paul A. Blanchard, of EG&G Dynatrend, for editing and preparing this document.

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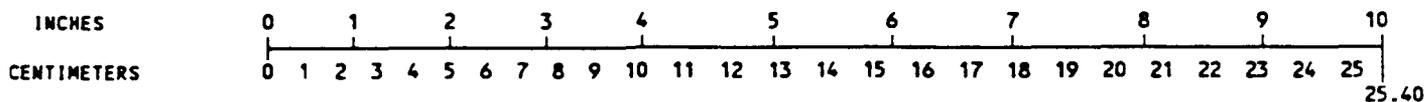
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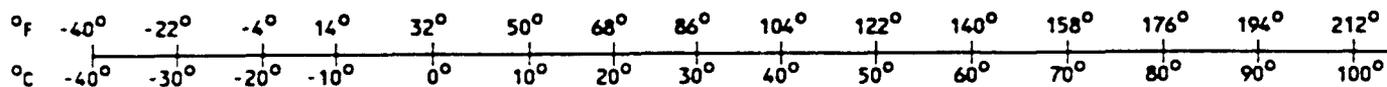
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ABBREVIATIONS AND ACRONYMS

AAS	Advanced Automation System
ACCC	Area Control Computer Complex
ACF	Area Control Facility
ACU	Azimuth Control Unit
ADAS	AWOS/ASOS Data Acquisition System
ADS	Automatic Dependent Surveillance
AMCC	ARTCC Maintenance Control Center
AN/FPS	Military Radar
ANR	Surveillance Program Directorate
AOS	Operations Support Service
APG	Azimuth Pulse Generator
ARSR	Air Route Surveillance Radar
ARTCC	Air Route Traffic Control Center
ASE	NAS System Engineering Service
ASM	System Maintenance Service
ASOS	Automated Surface Observation System
ASR	Airport Surveillance Radar
ASTA	Airport Surface Traffic Automation
ATC	Air Traffic Control
ATCBI	Air Traffic Control Beacon Interrogator
ATCRBS	Air Traffic Control Radar Beacon System
ATCT	Air Traffic Control Tower
ATIS	Automated Terminal Information System
ATR	Air Traffic Plans and Requirements Service
AWOS	Automated Weather Observation System
AWPG	Automated Weather Products Generator
AXD	Executive Director for System Development
AXO	Executive Director for System Operation
CD	Common Digitizer
CIP	Capital Investment Plan
CWP	Central Weather Processor
CWSU	Central Weather Service Unit
DARC	Direct Access Radar Channel
DAS	Data Acquisition System
DD	Design Document
DLP	Data Link Processor
DME	Distance Measuring Equipment
DMTI	Digital Moving Target Indicator
DOC	Department of Commerce
DOD	Department of Defense
FAA	Federal Aviation Administration
FSDPS	Flight Service Data Processing System

FSS	Flight Service Station
GMCC	General NAS Maintenance Control Center
GPS	Global Positioning System
IFF	Interrogate Friend or Foe
IFR	Instrument Flight Rules
IMCS	Interim Maintenance and Control Software
INCO	Initial Cut-Over
IRBT	Integrated Radar Beacon Tracker
ISSS	Initial Sector Suite System
JSS	Joint Surveillance System
LORAN	Long Range Navigation
LRR	Long Range Radar
MCC	Maintenance Control Center
MCS	Monitor and Control Software
MODE S	Mode Select: Discrete Addressable Beacon Radar System
MPS	Maintenance Processor System
MSL	Mean Sea Level
MWP	Meteorologist Weather Processor
MHz	MegaHertz
NADIF	NAFEC Dipole Fix
NAFEC	National Aeronautical Facilities Experimental Center
NAS	National Airspace System
NAWPG	National Aviation Weather Products Generator
NDI	Non-Developmental Item
NEXRAD	Next Generation Weather Radar
NOAA	National Oceanographic and Atmospheric Administration
NPI	New Program Initiative
NPRM	Notice of Proposed Rule Making
NWS	National Weather Service
OT&E	Operational Test and Evaluation
PAMRI	Peripheral Adapter Module Replacement Item
PIC	Peak Instantaneous Traffic Count
PIREPS	Pilot Information Reports
PRF	Pulse Repetition Frequency
PVD	Plan View Display
RAWPG	Regional Aviation Weather Products Generator
RBPM	Radar Beacon Performance Monitor
RCIU	Remote Control Interface Unit
RCL	Remote Communications Link
R E&D	Research, Engineering and Development
RML	Radar Microwave Link
RMM	Remote Maintenance Monitoring
RMMS	Remote Maintenance Monitoring System
RMS	Remote Monitoring Subsystem
RSCU	FPS Radar Set Control Unit

RSD	Real-time Status Display
RWDS	Radar Weather Display System
RWP	Radar Weather Processor
SAR	System Analysis Recorder
SEIC	System Engineering Integration Contractor
SR	System Requirements
SS	System Specification
SSR	Secondary Surveillance Radar
SSTMK	Solid State Transmitter Modification Kit
SUA	Special Use Airspace
TAAS	Terminal Advanced Automation System
TCAS	Traffic Alert and Collision Avoidance System
TCCC	Tower Control Computer Complex
TDWR	Terminal Doppler Weather Radar
TRACON	Terminal Radar Traffic Control
VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	VHF Omnidirectional Range
WARP	Weather and Radar Processor
WBS	Work Breakdown Structure
Wx	Weather
Xpndr	Transponder

EXECUTIVE SUMMARY

Overview

In August 1993, the FAA decided to deactivate long-range primary radars (LRR) in the en route environment when NEXRAD weather products can be provided to the ARTCC controller. It is estimated that this decision will save the government an expenditure of approximately \$1.4 billion by eliminating the need to replace the primary radars.

This report analyzes the implications of this decision and presents a transition strategy and plan that are cost effective and will enable an orderly transition from the present en route primary/secondary radar system to a beacon-only radar system in which NEXRAD provides weather information to en route traffic controllers. The key assumptions governing this study are:

- No degradation in flight safety;
- Surveillance system performance will remain at least equivalent to the present systems capabilities;
- Radar beacon and NEXRAD coverage down to 6000 feet will be available by the year 2000;
- A notice of proposed rule making (NPRM) that requires all VFR flights above 6000 feet and all IFR flights to be beacon transponder equipped and able to transmit altitude information.
- The JSS system will be upgraded with the ARSR-4 radars.

A systems engineering and integration approach has been used to derive the conclusions and recommendations provided in this report. The present system architecture and capabilities were analyzed; the planned system evolution prior to the decision was evaluated; changes to the future system resulting from the deactivation decision were determined; differences between the required future system and the present and planned system were identified; and a transition strategy and plan to evolve from the present system to the future system was formulated. Schedules and resources associated with the transition from the present primary/secondary system to the future beacon-only system were also derived. In addition, a series of issues and recommendations were identified during the course of the study and are documented in this report.

Surveillance System Architecture

The en route airspace surveillance system is presently composed of primary radar, secondary or beacon radar, and weather radar. The present en route architecture consists of air route surveillance radar (ARSR) with colocated air traffic control beacon

interrogator (ATCBI) on the same tower and sharing the pedestal, rotary joint, primary radar antenna reflector, and primary radar timing. Both radars are protected by a radome. The primary radar provides skin tracking of aircraft and limited weather reflectivity information. The beacon radar provides aircraft transponder replies to beacon interrogations for beacon tracking. The primary radar element of the ARSR is often referred to as a long-range radar (LRR). In addition, there currently exists a small number of beacon-only ATCBI systems. The terminal surveillance system architecture is similar to the en route system, but it provides a shorter coverage range and faster antenna scan. These radars include an ATCBI with a single beacon antenna mounted on the primary radar without a radome. In 1993 there were 116 long-range radars, 338 ATCBIs including 22 stand-alone sites, and approximately 200 ASRs. ASRs are not being considered for deactivation and hence are outside the scope of this study.

The current FAA Capital Investment Plan (CIP) calls for gradual increase in the number of en route and terminal area radar sites, some modernization of certain primary radars, and essentially wholesale replacement of current beacon interrogators with the newly developed Mode S equipment. By the year 2000 the number of ARSR sites with primary and secondary radar capabilities is planned to grow from 116 to 124. The number of beacon-only en route surveillance sites will grow from 22 (15 in CONUS) to 32 (7 in CONUS). 133 of the current beacon interrogators (25 beacons are intended for en route including 2 beacon-only sites) will be replaced by Mode S. The beacon system will consist of a total of 357 beacon radars including 205 ATCBIs, 19 military systems and 133 Mode S beacons from the "first buy".

The decision to deactivate the long-range radars changes the planned surveillance system architecture. After deactivation, the en route surveillance system architecture will consist of beacon-only radars and weather information will be provided to controllers from NEXRAD. A separate surveillance system known as the joint-use surveillance system (JSS) and consisting of modern long-range primary radars for national defense and drug interdiction will co-exist with the air traffic control (ATC) airspace surveillance system. In this future system, terminal and en route beacons will provide airspace coverage down to 6000 feet en route and to the ground in a majority of terminals. Table ES-1 provides a summary of surveillance radars for the current system, the pre-deactivation decision planned system, and the recommended post-deactivation decision future system.

Transition to Beacon-Only System

The transition strategy to a beacon-only system is based on a center-by-center implementation and assumes that the NEXRAD, WARP, and ISSS transition will have been completed at the center before the deactivation of the LRRs begins. This ensures that essential weather services continue uninterrupted, center-wide. Given this condition, center transition can be accomplished by simply "turning off" the primary radar input to the center once full beacon coverage is available. When all primary inputs to all centers from a particular radar have been eliminated, that primary radar can be decommissioned.

Table ES-1. Operational Radar Complement

RADAR TYPE	CURRENT	PLANNED	FUTURE
LONG-RANGE RADARS	116	124	66
ARSR-1	29		
ARSR-2	18		
ARSR-3	22	22	8
ARSR-x		60	
ARSR-4		41	41
FPS-20	45		
FPS-117 (JSS in Alaska)	2	1	1
FPS-117 (Mil. in Alaska)		16	16
BEACON RADARS	338	357	405
ATCBI-3	86		
ATCBI-4	85	38	
ATCBI-5	167	167	
Mode S		133	386
Military		19	19
NEXRAD RADARS		154	154
CONUS		139	139
Other		15	15

The center-by-center approach eliminates the need to coordinate with multiple centers and sectors associated with the shut down of a single radar. It is superior to a sector-by-sector approach which would limit sector reconfiguration flexibility. It is also consistent with the implementation strategies that will have already been successfully accomplished at each of the centers (e.g., Host and ISSS)

The transition schedule (Table ES-2) assumes a starting date of January 1, 1994. Transition at the first center beginning in 2000, or 2003, or 2008 represents three alternative implementation scenarios. The schedule identifies the initiation and completion of each of these elements and uses the heavily shaded bar for the optimistic scenario, the medium shaded bar for the most likely scenario, and the lightly shaded bar for the pessimistic scenario.

Two categories of programs and associated schedules support the deactivation decision. These are:

- LRR Sustain/Support Programs: and
- New and Modified Programs.

Table ES-2. LRR Deactivation Program Schedule

WBS Element/Year	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10
Program Management																	
Training																	
Test and Evaluation																	
Operational Activate/Deactivate																	
Facilities and Spares																	
Rules and Procedures																	
Aircraft/NPRM																	
ATC																	
Weather Surveillance																	
24-16 NEXRAD																	
43-02 WARP																	
63-02 CWP Interf.																	
Aircraft Surveillance																	
Sustain Primary Sys.																	
24-15 ARSR-4																	
44-39 Sustain																	
44-40 LRR Impr.																	
44-42 Radomes																	
44-43 Pedestal																	
Disposal of Radars																	
Impl. Beacon Sys.																	
24-12 Mode S																	
34-12 ATCBI Est																	
44-45 ATCRBS Rel																	
44-46 ATCBI Repl																	
MILESTONES																	
Scenario 1																	
Operational Transition																	
Scenario 2																	
Operational Transition																	
Scenario 3																	
Operational Transition																	

The programs in the Sustain Primary System category are required to extend the life of and maintain the existing LRRs until they can be decommissioned. In general, the sustain/support program requirements for the LRRs have been defined as a part of the CIP and consist of those listed under "Sustain the Primary System" in the above table with the exception of the ARSR-4 (24-15) which is required for the modern JSS system. LRR improvements are possible that will permit sustaining the LRRs for up to 15 additional years. This corresponds to the worst case scenario and while the schedule drives the total cost, it is technically feasible. If the transition can be initiated in the year 2000, only six years of full support is required and total cost will be lower.

The programs in the second category, i.e., new and modified programs, are required to implement the primary LRR deactivation decision and to change over to a beacon-only en route surveillance system. Programs in this category are generally listed under the heading "Implement Beacon System" in the above table. All other programs listed are new and must be defined and their associated cost estimated.

Resources Requirements

The initiation of the transition to a beacon-only en route surveillance system and the associated deactivation of the LRRs can not begin until at least the year 2000. It will, however, be necessary to sustain and maintain the LRRs until transition is complete. This requires that the sustain/maintain programs identified above be fully funded over the required time frame. Alternatively, radars could be decommissioned as failures occur and parts from failed radars used to maintain the remaining LRRs. This alternative is not recommended since system safety and efficiency will be compromised.

A summary of aircraft surveillance system costs associated with the implementation of the LRR decision is presented as Table ES-3.

Table ES-3. LRR Deactivation Costs

	LRR Deactivation Costs (in 1994\$M) for Aircraft Surveillance (1994 - 2002)	LRR Deactivation Direct Costs	Other En Route Surveillance Costs	Total Transition Costs
1.	Modernize/Extend the life of the LRRs		90.5	90.5
2.	Operate/Support 78 FAA LRRs	21.6	470.4	492.0
3.	Operate/Support 41 old and 40 new JSSs		272.4	272.4
4.	Operate/Support 17 Alaska AN/FPS-117		97.8	97.8
5.	Procure 25 Mode S sites (2 Beacon-Only)		105.0	105.0
6.	Estab. 53 Mode S new Beacon-Only sites		222.6	222.6
7.	Disestablish 78 LRRs	117.0		117.0
8.	Surveillance System Enhanc.(CIP 34-40)		180.0	180.0
9.	NEXRAD Implementation		510.0	510.0
10.	Additional Aircraft Transponder Costs	Not	estimated	
TOTAL		138.6	1,948.7	2,087.3

There are two types of costs associated with LRR deactivation. The first type results directly from the deactivation decision while the second type of cost is related to but not a direct result of the decision. The total costs are in excess of \$2.0B but, the costs directly related to the decision are approximately \$138.6M. Thus, the potential savings of approximately \$1.4B associated with the replacement results in a benefit-to-cost ratio greater than 10.

Issues, Recommendations and Conclusions

This study clearly demonstrates the feasibility of deactivating the FAA's LRRs and identifies an implementation strategy that could make this achievable by the year 2002.

Issues

Key issues related to NEXRAD, Mode S, and ATC Operation that require analysis and resolution are identified as follows:

NEXRAD-Related Issues

- **NEXRAD/ISSS Interface:** Deactivation of the LRRs is directly dependent on the presentation of NEXRAD weather products on the air traffic controller's display. Present plans are to provide the NEXRAD weather products to a controller using ISSS. Thus, the deactivation of the LRRs is contingent on success of the ISSS program, the NEXRAD interface, and the development of display presentation software. If a technique could be found, display of NEXRAD weather on the existing PVD is an alternative that would mitigate the dependence on ISSS.
- **NEXRAD Coverage:** According to NAS-SS-1000, surveillance and weather coverage is required in en route airspace down to 6000 feet. This requirement is also implied in the Decision Memorandum. Examination of the predicted NEXRAD coverage at 6000 feet shows that the coverage is less than presently provided by the en route radar system. This is a result of the plus 0.5° restriction imposed on NEXRAD radar for the lower end of scan angle, thus missing all targets below that angle and significantly reducing the radar coverage range in comparison to LRRs which have no such restriction. A study to determine methods to overcome NEXRAD coverage limitation is indicated.
- **NEXRAD Data Latency:** The present LRR system provides a complete weather update once every 12 antenna scans for two levels of weather detection. When three-level weather is implemented, updates will be accomplished every nine antenna scans. When NEXRAD is compared with LRRs, the NEXRAD will complete its full scan cycle in approximately 5 minutes (average rotation rate = 3.6 rpm, dwell time = 44 milliseconds per degree, total of 16 scans to cover all elevation angles) and process data in 6 minutes, where the LRRs will achieve a complete picture in approximately two minutes (12 scans at 5 rpm = 2.4 minutes).

The ARSR/NEXRAD comparison study¹ is being conducted but conclusive results are not yet available at this time. In addition, a six-minute latency presently violates NAS-SR-1000 requirements.

- **NEXRAD Availability:** NEXRAD is presently not being deployed with RMMS capability and it is recommended, prior to NEXRAD providing weather directly to controllers, that a determination of how the NAS-SR-1000 requirements associated with this essential information will be satisfied.

Mode S-Related Issues

- **Mode S Second Buy Decision:** This issue is focused on the Mode S second buy decision and the implementation schedule of the Mode S second buy sensors. In order to change over to a beacon-only system that provides beacon coverage to 6000 feet, additional beacon sensors are required.
- **Transition to Stand-Alone Beacon:** The conversion to beacon-only operation could be as simple as shutting off the primary radar or as difficult as converting the site to stand-alone Mode S operations. Decisions concerning the extent of this evolution must be made.
- **Mode S/Mode 4 Compatibility:** Concern has been expressed with respect to the compatibility of the operation of Mode S and Mode 4 at JSS sites. This concern requires resolution since the Mode S located at the JSS sites are necessary for ATC services down to 6000 feet.

ATC Operation Issues

- **Fail Safe/Soft Beacon Modes:** The primary radar has been available as a backup to the beacon system in the event of an aircraft transponder failure or a ground beacon radar failure. Once the LRRs are deactivated, this backup will no longer be available and use of other (non-radar) procedures will be required.
- **JSS Operation and Maintenance:** The issue is the need for the FAA to expend funds on JSS primary radars after transition to beacon-only surveillance and NEXRAD weather data.

¹NCAR (National Center for Atmospheric Research), ARSR/NEXRAD Comparison Study, Phase I, Dr. B. Carmichael, NCAR; presented at the System Design Review Team WEATHER AND SURVEILLANCE WORKSHOPS, Washington, D.C., 15-16 October, 1992.

Recommendations: Step-by-Step Approach to the Implementation

The following set of recommendations is presented in descending order of importance and represents a step-by-step approach to the implementation of the LRR deactivation decision:

1. Examine, modify, and initiate new CIP; R, F&D; and Operations programs required for or impacted by the deactivation decision;
2. Launch new programs such as coverage studies and en route beacon stand-alone antenna design modifications immediately so that timely funding adjustments can be made;
3. Start a cost/benefit study to confirm the cost/benefit advantage of the deactivation decision;
4. Use deactivated LRRs to help sustain operational LRRs;
5. Examine the siting of NEXRADs for improved coverage and the addition of RMS for improved availability;
6. Coordinate the transition to a beacon-only system with the NEXRAD implementation schedules;
7. Plan primary LRR removal and storage, site cleanup, and safe disposal of hazardous materials;
8. Accomplish beacon coverage to 6000 feet by integrating the terminal and en route beacon systems;
9. Initiate a Mode S second buy or beacon replacement program with options. The first option should be for the additional beacons required to achieve 6000-foot coverage;
10. Transition to beacon-only operation on center-by-center basis;
11. Begin the development of ATC rules and procedures for beacon-only operations including fail-safe and fail-soft considerations;
12. Introduce rule making for transponder carriage in a timely fashion so that aircraft are equipped by 1999 and be compatible with early transition to beacon-only operations;
13. Evolve to a JSS system composed exclusively of ARSR-4 and ARSR-3 radars;

14. Establish a stand-alone en route beacon system as a goal but do not make the certification of beacon-only operation at a center contingent on stand-alone beacon facilities;
15. Provide beacon system backup with overlapping coverage and eventually with ADS/GPS; and
16. Operate and maintain the JSS radars until it can be shown that it is cost effective to establish additional stand-alone beacons that duplicate the beacon coverage available from the JSS radars.

Conclusions

In conclusion, deactivation of the LRRs is feasible and cost effective. Random failure of LRRs can not be tolerated since this would be disruptive to air traffic control and would result in the unavailability of essential NAS weather services. The LRRs must be sustained and supported until an orderly evolution to NEXRAD and beacon-only capabilities are available. Sufficient beacon radars must be provided to cover the airspace down to 6000 feet. Transition to a beacon-only system can only take place after the NEXRAD weather products are available to the controller on a center-wide basis, provide the required airspace coverage, and satisfy operational requirements. Transition to beacon-only operations should be accomplished on a center-by-center basis. The NEXRAD/WARP/ISSS and the procurement of additional beacons are the pacing items associated with deactivation of the primary LRRs.

1. INTRODUCTION

1.1 BACKGROUND

The current en route surveillance system architecture is the result of the evolution of the Air Traffic Control (ATC) system. This architecture began with the development of primary radar during World War II and evolved to include the IFF or beacon system and weather surveillance functions. The first long-range radar (LRR) system, ARSR-1, was implemented in 1958. The beacon system which was introduced in the early sixties with its aircraft identification, barometric altitude reporting capability, and improved surveillance accuracy soon became the prime sensor for tracking aircraft while the primary radar provided weather information and a backup to the beacon radar. Over the years, the question concerning the value of continuing operation and maintenance of the en route, long-range primary radars has been raised several times.

Proponents of long-range primary radars argued successfully that many aircraft did not carry transponders and that safety would be compromised by deactivating the long-range radars. Others argued successfully that the LRR was critical to national defense and in particular, the joint-use surveillance system (JSS) radars were essential. Another successful argument that deterred the decommissioning of the primary LRRs was the requirement for weather information. Thus, while the operation and maintenance of the LRRs was costly, it was repeatedly concluded that the potential compromise to aviation safety and national security warranted the cost.

In 1990, a study of the LRR system was conducted by the Martin Marietta Corporation under joint sponsorship of the FAA's system operations and system development organizations. This study concluded that most IFR aircraft (97 percent) in en route airspace were transponder-equipped and that there would be no significant safety impact from deactivating the primary radars once the NEXRAD, a new weather surveillance radar, was available to provide the needed weather information. Similar conclusions were also reached by the Volpe Center¹ in a 1993 study. Based on statistics, the Martin Marietta study concluded that the number of probable additional accidents resulting from removal of primary enroute radars is insignificant.

The issues of national security, en route weather, and the percent of unequipped IFR aircraft, remain as concerns that could argue for maintaining and eventually replacing the aging LRR system at a cost of approximately \$1.4 billion. With respect to the issue of national security, the new ARSR-4 radars will replace most of the older JSS radars, except nine, thus continuing to provide the required security function. With respect to the weather information provided by the LRRs, deactivation will be delayed until after the implementation of NEXRAD. With respect to the unequipped IFR aircraft, a Notice of Proposed Rule Making (NPRM) will be issued by the FAA requiring that all IFR flights and VFR flights above 6000 feet be transponder-equipped with altitude information. This

¹Vilcans, Janis, *Impact of Shutting Down En route Primary Radars within CONUS Interior*, DOT/FAA/NR-93-1, June 1993.

strategy provided the groundwork necessary for the FAA to reach a decision to deactivate the primary LRRs.

1.2 THE FAA DECISION

The Decision Memorandum (Appendix A) was signed by the Executive Director for Systems Development (AXD) and the Executive Director for Systems Operations (AXO). The text, in part, states:

Deactivate the (primary) LRRs when NEXRAD weather products are provided to the controller. . . . This will save the expenditure of approximately \$1.4 billion. . . . In conjunction with this decision, AXO will issue an NPRM requiring transponders (with Mode C capability) on all IFRs at all altitudes and VFR flights above 6000 ft. after 1997.

Some of the salient features of the Decision Memorandum follow:

- The NAS includes 113 LRRs. After ARSR-4 replacement, approximately 84 LRRs will remain in the inventory;
- Some of the remaining LRRs are over 35 years old;
- There is no statement concerning continued support of the JSS radars;
- The memorandum does not discuss use of the ARSR-4 weather information once the NEXRAD is implemented; and,
- The mechanism for the deactivation of radars that perform both primary and beacon functions is not addressed.

In summary, the Decision Memorandum is not sufficiently clear to be a basis for action without interpretation. Several items that reflect the interpretation adopted for this study are listed as assumptions in Section 1.4.

1.3 OBJECTIVES AND SCOPE

The objective of this report is to provide a set of implementation recommendations addressing the methodology for proceeding with the FAA decision to deactivate the LRRs. The scope of this effort is to include², at a minimum, the requirements, programs, resources, and schedules associated with the implementation recommendations and the impact of these recommendations on the National Airspace System (NAS) and its users in the immediate, three-to-five, and ten-year time frames.

²ANR-400 Program Office for En route Radar memo of September 13, 1993

1.4 ASSUMPTIONS

The assumptions governing the conduct of this study are based on interpretation of the LRR deactivation Decision Memorandum and are presented below:

- No degradation of the quality of weather products relative to the existing levels. This assumption implies that the NEXRAD products must at least be equivalent to the existing ones or that the differences be acceptable to the air traffic controllers and not compromise flight safety. These considerations include coverage, intensity measurement, accuracy, resolution, and data latency.
- No degradation of aircraft surveillance performance from the existing levels. This implies that the future beacon-only system will provide equivalent surveillance performance and coverage and not compromise flight safety. The backup provided by the primary radar has been shown to be of little consequence to the overall safety of the system.
- The Notice of Rule Making (NPRM) will be published on schedule and the new rule will be successfully implemented.
- 1995 is the earliest possible date to establish FY-97 funding for new and modified programs required to fulfill the LRR deactivation decision.
- NEXRAD products will be available to controllers by the year 2000.
- JSS sites will be maintained and will consist only of ARSR-3/4 and FPS-117 radars. The ARSR-3 Leapfrog program³ has been cancelled and has not been reinstated and initially planned sites are being continuously changed.
- NAS-SR-1000 requirements pertaining to the weather and surveillance functions must be satisfied (Appendix B).
- NAS-SR, DD, SS-1000 provide the baseline data for the system analyses conducted in this study.

1.5 CRITICAL ISSUES

Implementation of the FAA's LRR deactivation decision is dependent on successful resolution of the following critical issues:

- Which CIP; R, E&D; and Ops programs are impacted by the LRR deactivation decision and affect successful implementation.

³ARSR-3 Leapfrog deployment plan before cancellation: Mt Laguna, CA to San Pedro, CA; Mt Kaala, HI to Burns, OR; Rocksprings, TX to Arbuckle, OK; Cross City, FL to Haleyville, AL; Ft Lonesome, FL to Samburg, TN; Nashwauk, MN to Tyler, MN; Lakeside, MT to Sand Springs, MT; Riverhead, NY to Benton, PA; Empire, MI to Medford, WI; Finley, ND to Salt Lake, UT.

- How compliance with the 6000-foot en route surveillance and weather coverage requirement as specified by the NAS-SS-1000 and implied by the issuance of the NPRM will be achieved.
- How NEXRAD products will be provided to the controller.
- Will controllers accept NEXRAD weather data latency.
- What availability, reliability, and RMMS requirements must be satisfied.
- JSS coverage, and operational and maintenance issues between the military and FAA such as cost sharing and maintenance responsibility.
- Availability of backup and fail-safe/soft beacon modes.
- Design issues including coexistence of Mode S and ATCRBS in the ATC environment and compatibility with JSS Mode 4 operation; limitations in transmission of weather data to pilot displays; and development of a single weatherproof beacon antenna without a radome.
- The unresolved issue on three-level weather data usage from ARSR-4 and other JSS sites for future ARTCC processors/displays.

1.6 APPROACH OVERVIEW

The top-level approach used in this study is best described by considering the work flow diagram provided as Figure 1-1.

There are three essential components of this effort. The first involves determining requirements imposed by the deactivation decision on the future system. In this component of the study, the future en route surveillance system architecture is defined in terms of the following types of radar sites:

- Residual secondary radar/beacon installations at existing LRR sites;
- Relocated sites;
- New sites;
- NEXRAD Radar sites;
- Terminal Beacon sites;
- JSS sites; and
- New terminal radar establishments resulting from loss of LRR coverage.

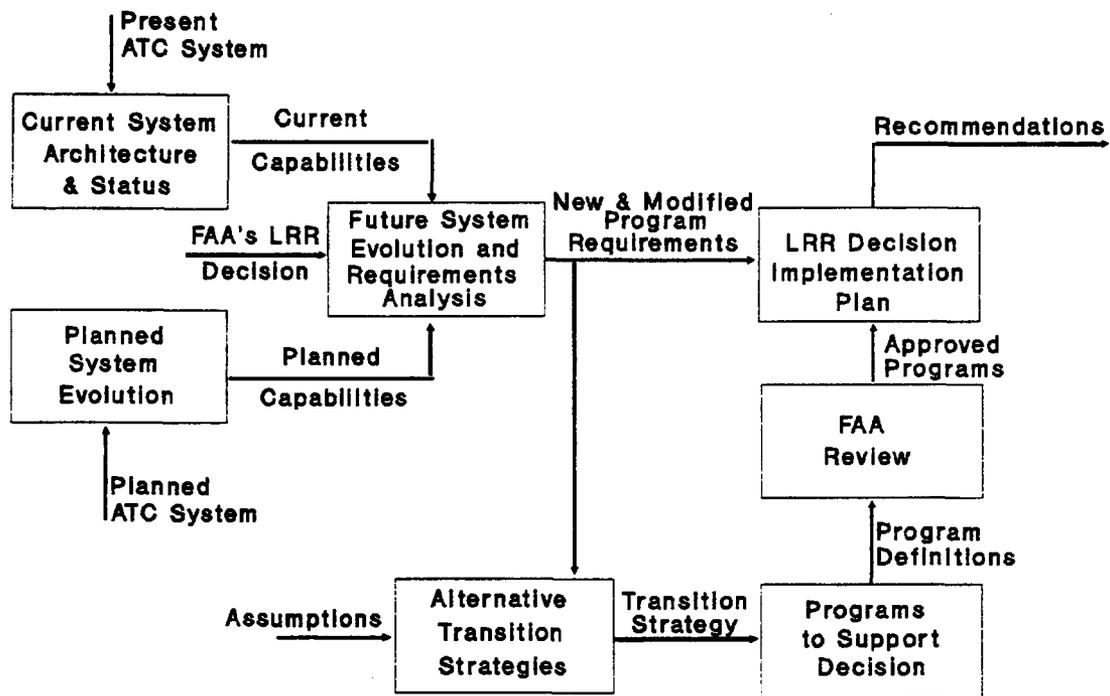


Figure 1-1. LRR Deactivation Study Work Flow Diagram

The definition of beacon-only site configurations is also required and includes:

- Beacon Type;
- Antenna Type;
- Tower Type/Height;
- Radome/Pedestal;
- Rotary Joint;
- Building Type;
- Clear Zone; and,
- Range (to achieve a 6000-foot coverage).

TDWR is not included in the future en route surveillance system architecture, because the TDWR real-time weather data will not be available in the ARTCC at the controller console.

Programs to satisfy the requirements are included as part of this study component. Other programs to sustain primary radars and to provide JSS coverage and maintenance are also addressed.

The second component of this effort focuses on the selection of a transition strategy that evolves the system from the present to the future architecture. This process involves the formulation of a set of feasible alternative strategies and the evaluation and selection of the most effective and efficient strategy given the program requirements and the resource and schedule constraints.

The last component of the study requires a detailed analysis and examination of the selected strategy and the new and modified program requirements. This will yield a set of positive recommendations for the implementation of FAA's LRR deactivation decision.

1.7 ORGANIZATION OF THE REPORT

This report is organized according to the major study components described in the previous section. Thus, Section 2 is devoted to primary LRR deactivation requirements analysis. It consists of three subsections focusing in turn on the existing and planned system; the future system resulting from primary LRR deactivation; and the requirements resulting from the deactivation decision. The principal result is the identification of implementation program requirements.

Section 3 addresses the definition of the primary to beacon transition strategy and the associated implementation plan. It consists of two major subsections. The first develops a set of feasible transition alternatives and selects a transition strategy. The second develops the implementation plan consisting of the costs, milestones, and schedule for the selected transition alternative.

Section 4 provides a discussion of the issues, recommendations and conclusions resulting from the deactivation decision implementation program requirements and the selected transition strategy.

2. LRR DEACTIVATION REQUIREMENTS ANALYSIS

Implementation of the deactivation decision will require modifications to existing primary LRRs and related programs and the initiation of several new programs. This section is organized with three major subsections one for each of the three components of the requirements analysis methodology: the first describes the present system; the second the planned system (i.e., pre-primary LRR deactivation decision); and, the third the desired future system (i.e., post-primary LRR deactivation decision). The program requirements that result from comparing the pre- and post-deactivation decision systems are also developed in the third subsection.

The methodology used to define these program requirements is presented as Figure 2-1, a subset of Figure 1-1.

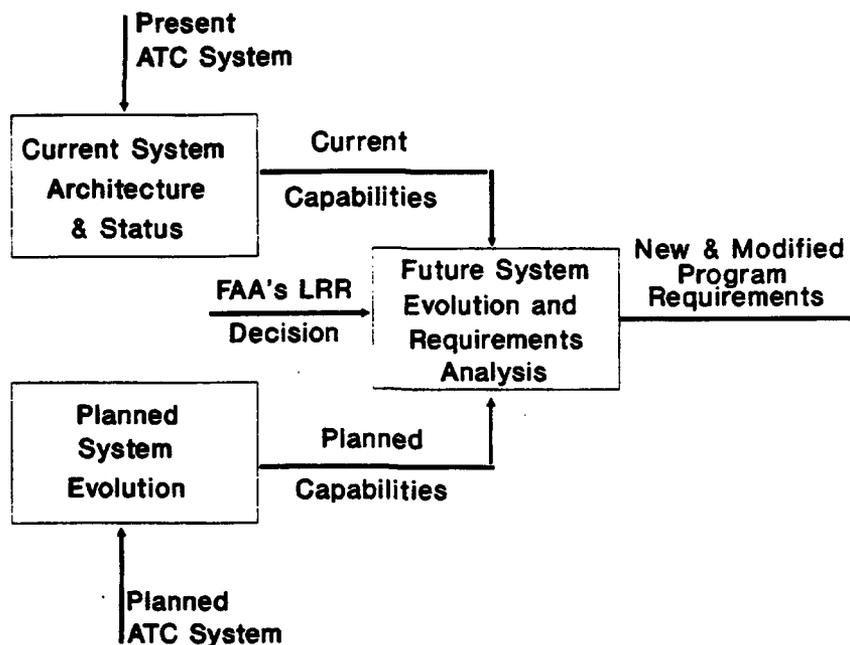


Figure 2-1. Requirements Analysis Methodology

2.1 CURRENT EN ROUTE SURVEILLANCE SYSTEM ARCHITECTURE AND SYSTEM STATUS

The current FAA en route radar surveillance system consists of 116 long-range radars which include 29 ARSR-1, 18 ARSR-2, 22 ARSR-3, 45 FPS-20 and 2 FPS-117 primary radars equipped with traffic control beacon interrogators (ATCBI). The primary radars operate at L-band and provide limited quality weather reflectivity (precipitation) surveillance information. The beacons also operate at L-band and provide aircraft identity and altitude information. The FAA's deactivation decision will affect 78 of the FAA en route primary radars, specifically ARSR-1, ARSR-2, ARSR-3, and FPS-20 radars.

As a part of NAS ATC system, primary radar currently performs five specific surveillance functions. In decreasing order of importance, these functions are:

1. Detection of real-time weather information;
2. Detection of non-transponder equipped aircraft;
3. Detection of aircraft with failed transponders;
4. Backup to beacon radar ground equipment failure; and,
5. Enhancement/reinforcement of beacon radar surveillance data.

In the following discussion, en route aircraft surveillance, en route weather surveillance, and the status of the systems required to perform these functions will be addressed in separate subsections.

2.1.1 En Route Aircraft Surveillance System Architecture

The en route aircraft surveillance system presently consists of long-range primary radar systems, with colocated secondary or beacon radars on the same tower and sharing common components, and also supported by a few beacon-only sites. The primary radars provide non-cooperative target surveillance while the beacon system detects only those targets that are equipped with an ATCRBS or a Mode S transponder. Both systems provide measurements of the target range from the radar and azimuth relative to true north. The beacon system provides additional information concerning the identification (Mode A) and altitude (Mode C) of the target. These data are provided from the aircraft transponder 4096 code and a separate altimeter. Only the new 3-D ARSR-4 and FPS-117 en route radars have the capability to independently provide coarse altitude data (3000-foot accuracy).

Surveillance data processing is presently performed in the Air Route Traffic Control Centers (ARTCCs) with limited processing taking place at the radar sites. The primary and beacon radar data is transmitted to the ARTCCs using FAA communications facilities. At the ARTCC, data from multiple radar sites are combined, processed to establish radar

tracks, and displayed to the air traffic controllers on plan view displays (PVD). The NAS Surveillance Network data flow diagram is presented in NAS-DD-1000 and is provided as Figure 2-2.

EN ROUTE SURVEILLANCE RADARS

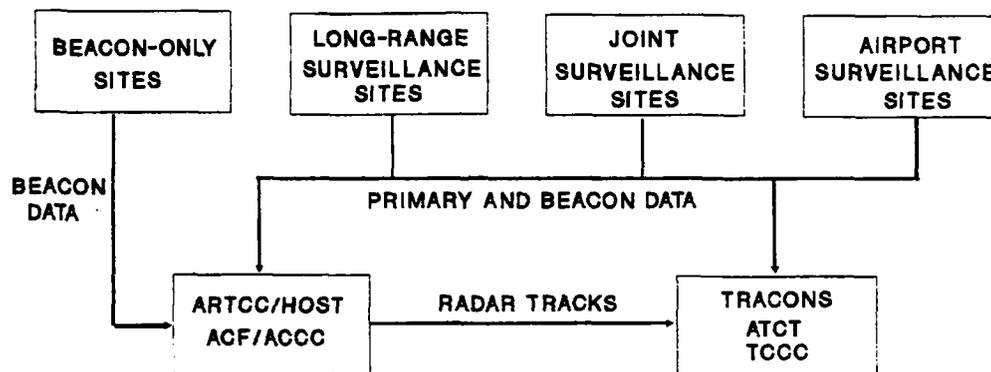


Figure 2-2. NAS Network Data Flow

There are presently two distinct sensor architectures for en route radars:

- Primary/Secondary Dual Radar Architecture - At en route installations both radars are colocated and share common components including the tower, shelters, pedestal, radome, primary antenna reflector, timing, and rotary joint;
- Stand-Alone Beacon Radar - consisting of a beacon system and generally used as a gap filler in areas where dual sensor coverage is not available. There are 22 beacon-only en route sites in the NAS, fourteen of which are in CONUS.

The vertical coverage provided by the NAS en route radars is illustrated in Figure 2-3. In this graphic, the vertical coverage requirements of both the primary and secondary radars are presented.

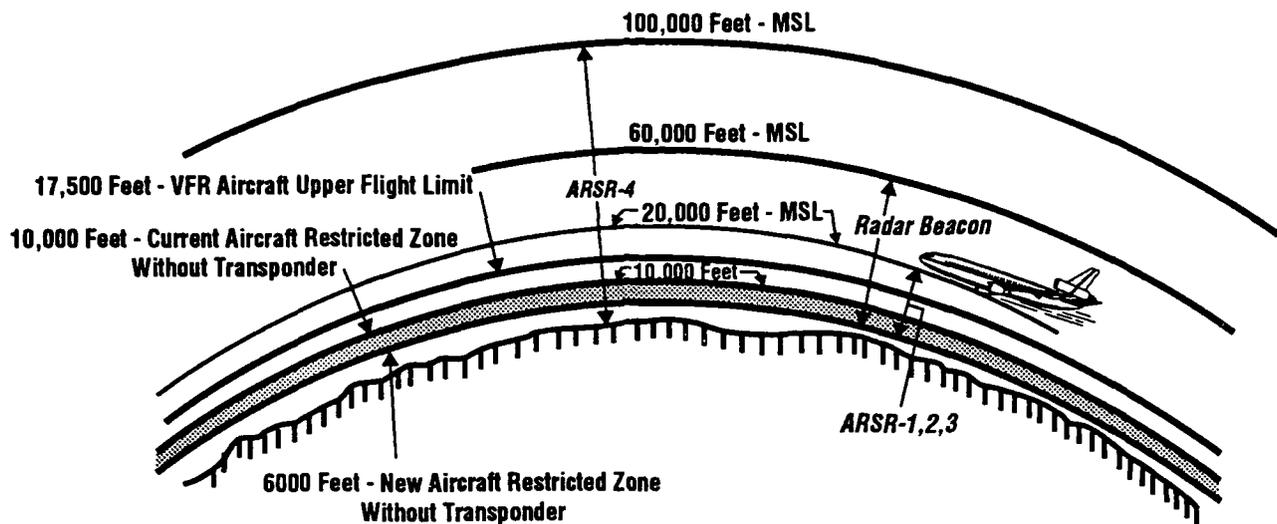


Figure 2-3. NAS Vertical Radar Coverage Requirements*

* Only required altitude coverages are shown. The actual radar altitude range capability is far beyond the altitude levels indicated.

2.1.1.1 En Route Primary Surveillance System Architecture

The primary radar system has several functions which include:

- National Defense (JSS Radars)
- Drug Enforcement Assistance
- Air Traffic Control Surveillance
- Weather data (Radar Remote Weather Display System (RRWDS)) for the National Weather Service (NWS) at the Flight Service Station (FSS).

The five specific surveillance functions provided for the ATC were identified in Section 2.1 above.

The primary radar systems that constitute the present and planned inventory are presented as Table 2-1. Performance characteristics are provided in Appendix C.

**Table 2-1. The Current NAS En Route Primary Radar Surveillance Architecture Prior to ARSR-4 Deployment
(See Appendix H, Part 1 for Details)**

RADAR	JSS SITES		NAS/FAA SITES	
	Current CONUS Sites	Current Outside CONUS Sites	FAA Sites	Total Current Sites
FPS-117		1	1	2
FPS Series	17	1	22	40
ARSR-1	11		18	29
ARSR-2	2		16	18
ARSR-3	10	2	10	22
ARSR-60	2		2	4
None	1*			1*
TOTAL	43	4	69	116

* The long-range radar FPS-117 at Gibbsboro, NJ site, has been relocated to Murphy Dome, AK, and temporarily without radar, but is scheduled for recommissioning with ARSR-4 in 1994.

Table 2-2 presents planned primary radar deployment and locations in Appendix H.

Table 2-2. Planned JSS, Military, and FAA Site Locations and Radar Types After ARSR-4 Deployment (See Appendix H, Part 2 for Details)

RADAR	JSS			Military	FAA TOTAL	TOTAL
	CONUS	Alaska	Pacific	CONUS/ Caribbean		
ARSR-4	38		2	2	1*	43
FPS-117		17				17
FPS-Series	1		1		20	22
ARSR-1	3				20	23
ARSR-2	1				16	17
ARSR-3	1	1			20	22
ARSR-60					2	2
Other		1**				1
TOTAL	44	19	3	2***	79	147

* FAA Academy (AERO) ARSR-4 site is not an operational site, therefore, not included in transition costs;

** St. Paul Island, AK, JSS Beacon-Only site;

***Two Military-Only sites: San Clemente, CA; and Guantanamo, CU.

The present geographic distribution of all CONUS en route radars is presented as Figure 2-4. The primary radar coverage provided by these radars is presented in Appendix D and the present and planned locations in Table 2-2 and Appendix H. Appendix D provides the coverage contours for all CONUS en route primary radars as planned in the future including: the ARSR-4 radars alone; the combination of the ARSR-3 and ARSR-4 radars; and, the combination of all en route primary and secondary radars according to the projected NAS site locations.

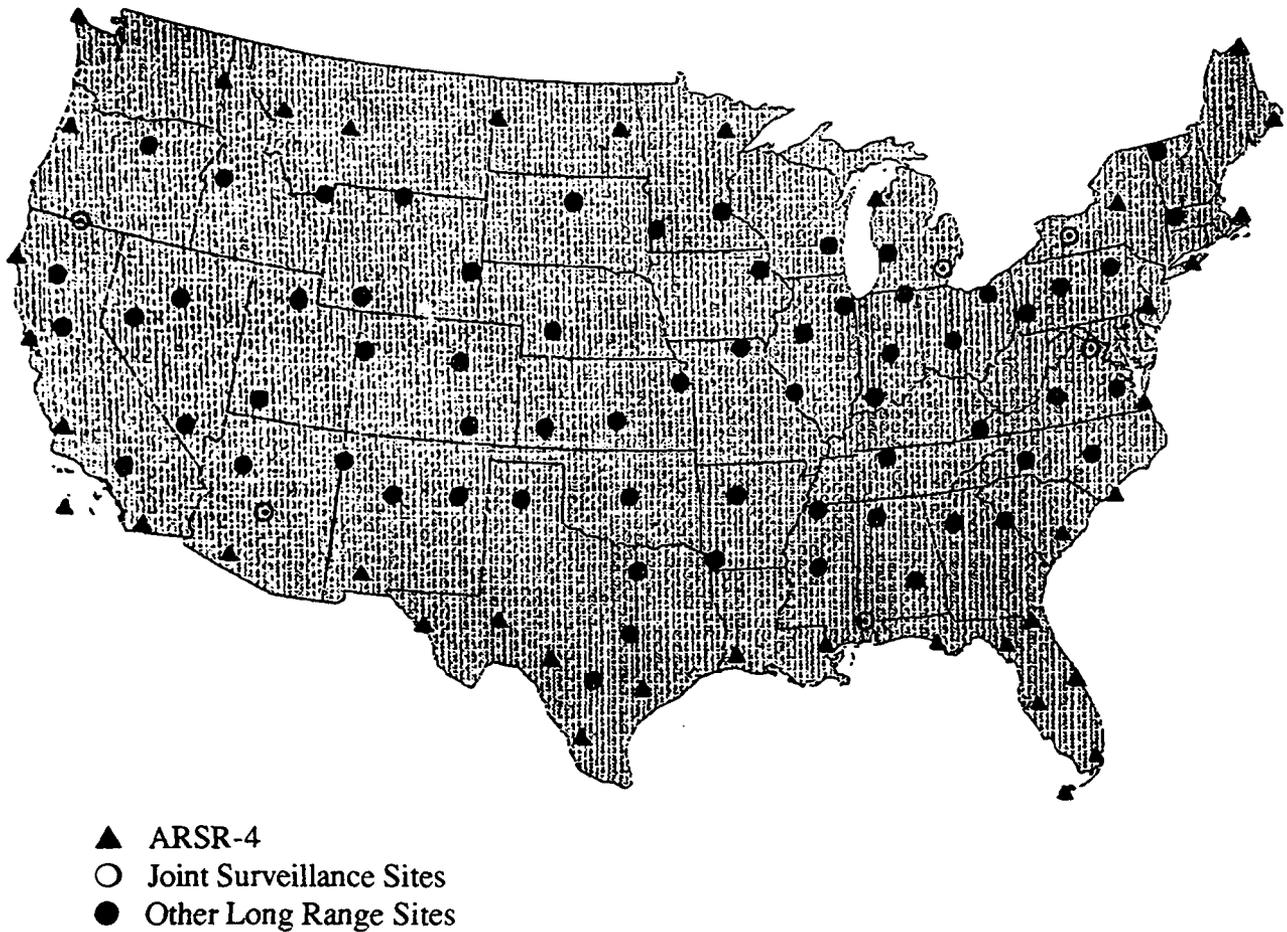


Figure 2-4. En Route Primary Radar Locations in CONUS¹

¹Doug Hodgkins, ASE-300/ Paul Grady, Martin Marietta.

At the completion of the ARSR-4 implementation, the JSS sites in CONUS will include 38 ARSR-4 sites plus 6 older sites and 1 military-only site, a total of 45 non-FAA sites. Alaska sites will include 17 AN/FPS-117 radars, 1 ARSR-3 and 1 beacon-only site, a total of 19 sites. The 3 Pacific sites: ARSR-3 (Mt. Kaala) and FPS-93 (Mt Santa Rosa, Guam) will receive ARSR-4, and FPS-93 site (Mt. Kokee, HI) to be determined. The 8 radar sites to remain with present equipment are: Kenai, AK, (ARSR-3); The Plains, VA, (ARSR-3); Detroit, MI, (ARSR-1E); Keno OR, (FPS-67B); Phoenix, AZ, (ARSR-1E); Grand Bay LA, (Citronelle, AL) (ARSR-2); Mt. Kokee, HI, (FPS-93); Dansville, NY, (ARSR-1).

Locations of the JSS sites in CONUS are shown in the sketch below (Figure 2-5).

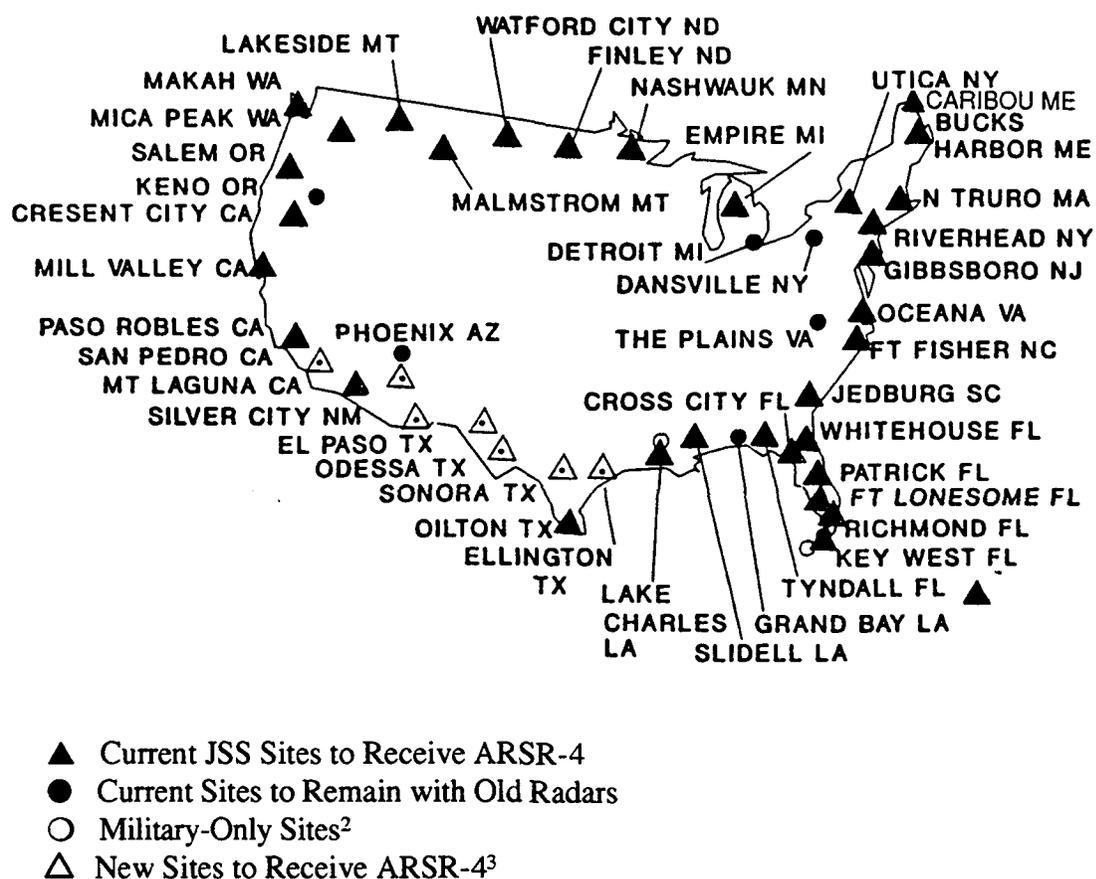


Figure 2-5. JSS Site Locations in CONUS

²Two military-only sites are also identified as FAA sites: Lake Charles, LA and Key West, FL.

³Seven new sites in CONUS to receive ARSR-4: Ajo, AZ; Deming, NM; Eagle Peak, TX; King Mountain, TX; Morales, TX; Rock Springs, TX, are JSS sites and San Clemente, CA, military-only site.

Primary radar data is input to ARTCC automated tracking/surveillance processing in two forms by the common digitizer (CD):

- If a primary report does not correlate in position with a beacon report, it is reported as a "primary target" and its range and azimuth are provided. ARTCC automation does not form tracks on such data although controllers can initiate tracking on these targets if they wish. A primary target is displayed as an "X" on each scan if tracked and if not tracked as a "+" or "•" depending on the intensity of the primary return.
- If a primary target correlates with a beacon target, the primary target report is not sent to the ARTCC. Rather, a bit is set in the beacon target report to indicate "radar reinforcement."

Because secondary radar "false targets" are not uncommon, the controller can employ the reinforcement bit as another information source in instances where there is some uncertainty concerning a target.

2.1.1.2 En Route Secondary (Beacon) Surveillance System Architecture

The beacon system has a singular function, i.e., to track cooperative targets. Beacon radars are colocated with the primary radars at all LRR and Airport Surveillance Radar (ASR) sites, and at 22 stand-alone beacon sites. Of these 22 beacon-only radar sites, 14 are located in CONUS, 7 outside CONUS, and 1 JSS site at St. Paul Island, Alaska. The total number of beacon systems in the beacon radar inventory at the present time is 338 beacon radars consisting of:

ATCRBI-3	86
ATCRBI-4	85
ATCRBI-5	167
Total	338

The radar coverage provided by the beacon system is shown graphically in the coverage charts contained in Appendix D. It is also important to mention that in addition to the ground system component, the radar beacon system requires that aircraft be equipped with a beacon transponder. Presently, approximately 97 percent of aircraft flying in the en route IFR system are equipped with transponders.

Since the FAA uses the beacons located at JSS sites and since the military uses the secure interrogation mode known as Mode 4, it is essential that the ATC beacon interrogation modes and Mode-4 be compatible. In the ATCRBS system Mode A and Mode C interrogation modes are used and are compatible with Mode 4. There is, however, concern that Mode S may be incompatible with Mode 4 and this issue remains to be resolved.

2.1.2 En Route Weather Surveillance System Architecture

In order to understand the en route weather surveillance system architecture, it is important to examine the total en route weather system and the role of the radar. A schematic of the en route weather system architecture is presented as Figure 2-6.

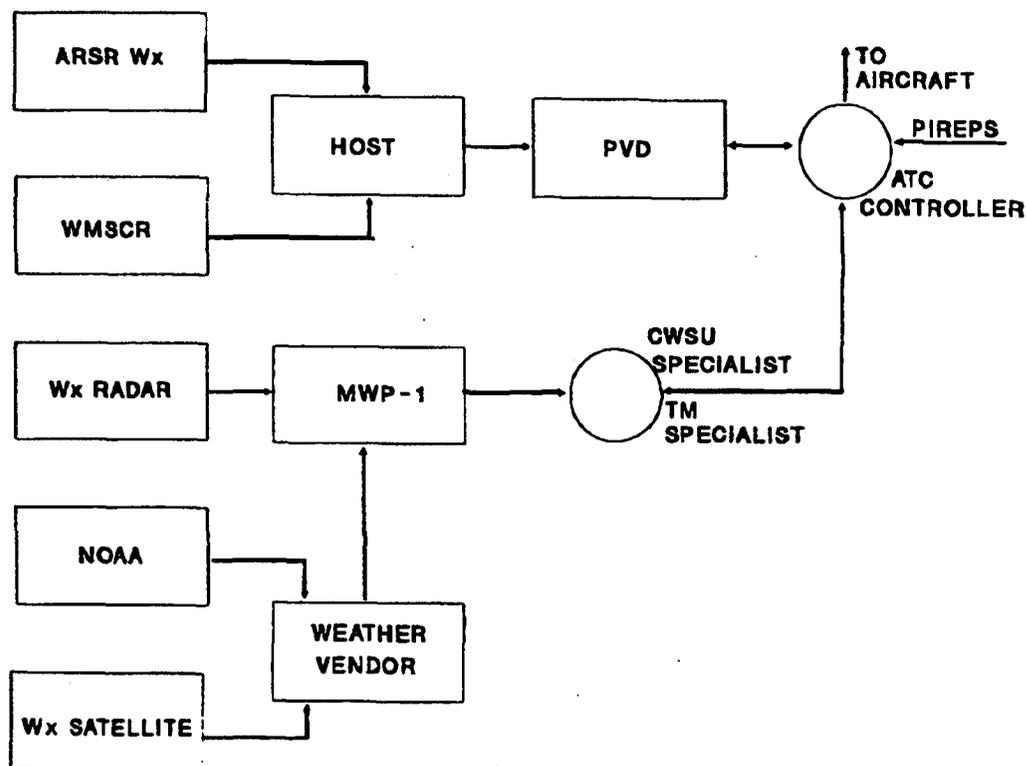


Figure 2-6. En Route Weather System Architecture

Weather phenomena that are detected by the LRRs are processed in the host computer and displayed to controllers. Specifically, regions of airspace containing radar returns attributed to "moderate" precipitation are displayed on the controller's PVD as a series of adjacent radial lines. "H"s are placed adjacent to the lines if the weather is deemed "heavy" (this is called "Two-Level" weather capability) - see Figure 2-7.

A wide variety of weather information is available in the ARTCC from many sources including:

- Real-time precipitation information from the primary radars which is available directly to the controller on his PVD;

- Real-time precipitation from the primary radars and NOAA weather radars available to the CWSU specialist from the Meteorological Weather Processor (MWP) and displayed at the CWSU work station;
- Various forecasts and hazardous weather warnings with limited size information; and
- Pilot-reported phenomena, generally associated with hazardous conditions including clear air turbulence, volcanic ash, migratory birds, and other hazards not readily detected by radar.

PHOTOGRAPH OF ARSR DATA ON PVD

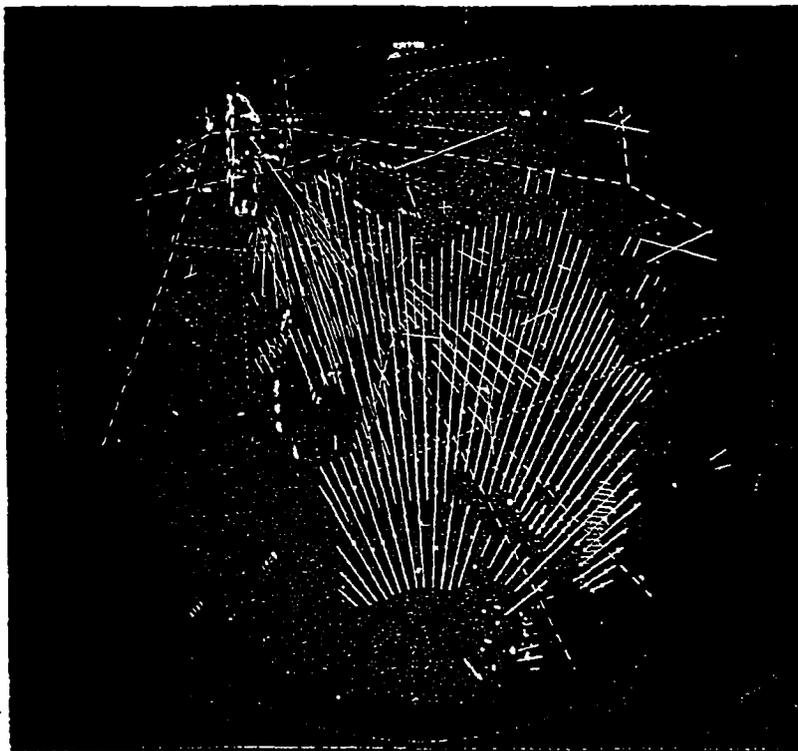


Figure 2-7. ARSR-derived Weather Data

Controllers report frequent major discrepancies between ARSR weather data and information available from other sources such as pilots and weather service radars. Weather surveillance coverage of the en route airspace is the same as that provided by the ARSR-1, -2, and FPS and also ARSR-3, -4 shown in the coverage charts provided in Appendix D.

2.1.3 Status of Present System

The present en route system is old. Some of the LRRs were installed more than 30 years ago; maintenance costs are increasing and replacement parts are becoming very difficult to obtain. The system requires modernization. Some of the needed upgrades have been completed and others are being planned.

The Solid-State Receiver/Digital Moving Target Indicator (SSR/DMTI), which replaced the old vacuum tube primary receivers at 70 en route sites, has been completed. A replacement for the transmitter subsystem at these facilities was planned but the Mission Need Statement (MNS) was canceled in May of 1992. Selected upgrades are still needed and being planned for these radars to improve reliability and maintainability.

The en route ARSR-1, -2, and FPS-20 required a solid-state transmitter modification and additional waveguide filter. This modification was to clean up the in-band spectrum of the magnetron and amplatron transmitter pulses and out-of-band interference between the primary and Mode S systems. To protect all three Mode S receiver channels, a filter was placed in each of sum, difference and SLS ports to attenuate incoming RF energy such as may be received from the primary and other colocated radars. The FAA Technical Center will test for this interference at the Elwood, N.J. site when Mode S is delivered. If the interference is present, then alternate solutions for elimination of the interference must be found.

Common Digitizers (CD) are employed at all existing LRR facilities to convert analog radar signals to digital for transmission to, and processing by, digital computers located at the ARTCCs. A Common Digitizer "Get-Well Plan" is currently being funded to resolve some supply/support and obsolescence problems.

The ARSR-4 project will be the most significant upgrade and will be installed at most of the old primary JSS radars. These new solid-state radars will have full RMM capability and an internal digitizer which will replace the common digitizer.

Some of the secondary radars at en route facilities such as the ATCBI-3s are also more than 30 years old and need to be replaced. The ATCBI-3s as well as some of the ATCBI-4s are planned to be replaced with the first Mode S buy. The remaining ATCBI-4s and ATCBI-5s are planned to be upgraded to Mode S, if the second buy is realized.

Even with the above mentioned upgrades, the existing system is on the verge of compromise. The older systems, with the exception of the ARSR-4 and the Mode S systems, will continue to experience high maintenance costs and difficulty in obtaining replacement parts due to obsolescence. These systems cannot take advantage of the modern Remote Maintenance Monitoring System (RMMS) and the maintenance concept of the '90s. While the decision to shut down the primary LRRs provides an eventual solution to the maintenance and obsolescence problems, it is essential to continue to

provide support and selected upgrades to these systems until the decision can be implemented.

2.2 EN ROUTE SURVEILLANCE SYSTEM ARCHITECTURE PLANNED EVOLUTION

The top-level evolution of the en route surveillance system architecture, as planned prior to the deactivation decision, is documented in the Capital Investment Plan (CIP), and other FAA system documentation. In the following section, snapshots of the en route surveillance system will be provided for the years 1998 and 2005. Table 2-3 provides an overview of the possible evolution of the en route surveillance system through the year 2030.

Table 2-3. En Route Surveillance Evolution Path

94 95 96 97 98	99 00 01 02 03 04 05 06 07 08	09 10 11 12 13 14	15 20 25 30
Present System	Transition to Beacon-only Surveillance	Transition to Dependent Surveillance	Transition to Satellites
INDEPENDENT NON-COOPERATIVE AND COOPERATIVE SURVEILLANCE	INDEPENDENT NON-COOPERATIVE SURVEILLANCE PHASE OUT	COOPERATIVE AND DEPENDENT SURVEILLANCE	COOPERATIVE BEACON PHASE OUT
Primary Radars ATCBI-3, -4, -5 and some Mode S	ATCBI-4, -5 and Mode S	Mode S ADS/GPS	All Satellite Surveillance ADS/GPS

2.2.1 En Route Aircraft Surveillance System Planned Evolution

The planned evolution of the en route aircraft surveillance system prior to the decision memorandum consists of the following major elements:

- Implementation of the ISSS segment of AAS automation effort;
- Replacement of some of the aging ARSRs with new ARSR-4s;
- Implementation of the Mode S Beacon System.

The implementation of the ISSS, which includes the replacement of the PVD with the Common Console Sector Suite, is the major change that will be evident to the controller by the year 2005. By this time, the Area Control Computer Complex (ACCC) may have replaced the host computer and additional automation and functionality may be provided to the controller. Radar beacon data, however, will be processed much the same as it is today, with perhaps some data processing improvements resulting from the ISSS and the ACCC.

2.2.1.1 En Route Primary Surveillance System Planned Evolution

Presently, there are 116 en route primary radars identified in Table 2-1. The planned evolution includes procuring an additional 60 ARSR-3, or ARSR-4, or NDI units to replace the ARSR-1, 2 and FPS-20 series radars. In addition to the FAA and JSS radars, Alaska is equipped with 17 FPS-117 FAA and military radars.

This would result in the following configuration for NAS:

AN/FPS-117	1
ARSR-4 (including the FAA AERO site)	41
ARSR-3	22
ARSR-X	60
Total NAS En Route Radars	124

This plan would increase the CONUS coverage by adding seven LRRs. The plan must be changed to accommodate the LRR deactivation decision.

Specific site locations for all radar installations have been identified and the evolution of the en route primary radar site locations and associated coverage can be evaluated. To complete the primary surveillance system picture, there are 254 projected terminal-type radars planned in the NAS-SS-1000. These are:

ASR-9	124
ASR-7, 8 Gap fillers	9
ASR-X ⁴	100
ASR-9 Military owned gap fillers	2
ASR-9 Military	19
Total	254

Recent decisions have resulted in the cancellation of the ASR-10 program and the creation of the ASR-11 program. The terminal radars used as gap fillers to supplement the en route primary system may also be candidates for deactivation.

2.2.1.2 Search and Rescue Issue⁵

In the future, without primary LRR surveillance, assisting lost aircraft or aircraft in distress becomes an issue. Search and Rescue is a service which provides these functions. It is a cooperative effort using the facilities and services of available Federal, State and local agencies. This service is not an option. Search and Rescue services depend heavily on the use of primary radar. There is no direct alternative to primary radar to help find

⁴Undecided - ASR-7, 8, 11 or Non Development Item (NDI).

⁵FAA Order 7110.65

and orient lost aircraft. Therefore, in the beacon-only system, this service would no longer be available.

The impact of primary non-cooperative surveillance radar on the lost aircraft accident rate in the en route environment was studied⁶ and it was concluded that the deactivation of en route primary radar would likely increase the number of accidents to non-transponder-equipped lost aircraft in the Continental United States (CONUS) by only one additional accident over 18 years. The primary radar has serious limitations including: the radar horizon limitations; poor en route coverage below 6000 feet (not required); and poor reception in bad weather, when needed most.

In order to minimize the primary radar shutdown impact on search and rescue, an aircraft with voice-reporting capability or with squitter mode can broadcast the onboard GPS-derived position information providing coverage to ground zero, which is not always achievable by radar. An alternative is to employ a direction finding technique based on aircraft voice reports using Direction Finding (DF) system. A Traffic Alert Collision Avoidance System (TCAS) is becoming available in the future.

2.2.1.3 En Route Secondary Surveillance System Planned Evolution

The planned en route beacon system will be dramatically changed from the present beacon system with the implementation of Mode S since all existing ATCRBIs are eventually planned to be replaced with Mode S or a similar monopulse system. There are two buys of Mode S planned; the first for 137 systems (133 operational) and the second for 259 systems. With the first buy, all tube-type beacon radars will be replaced and 12,500 foot (MSL) Mode S altitude coverage throughout CONUS will be achieved. The focus for the first buy is on the terminal system with only 25 Mode S sites planned for en route. A final decision to proceed with the second Mode S buy has not been made.

By August 1996, after completion of the first buy, the beacon system will include:

ATCRBI-4	38
ATCRBI-5	167
Mode S (108 terminal and 25 en route sites)	133
Military Beacons	19
Total	357

The geographic distribution proposed for the future (2005) beacon radar system sites is provided as Figure 2-8. In total there will be 386 Mode S FAA sites of these 32 beacon-only sites.

⁶Impact of Primary Surveillance Radar on Lost Aircraft Accident Rate in the En Route Environment. Joel M. Yesley, FAA, and Richard W. Kitterman, Martin Marietta Air Traffic Systems, November 1991.

The anticipated Mode S second buy (now on hold) will replace all ATCBIs and add seven new sites. The second buy will result in the following beacon system configuration:

Mode S operational systems first and second buy	386
Military Beacons	19
Total	405; (32 beacon-only)

The intended 32 beacon-only (Mode S) site deployments are: CONUS -7, Alaska-21, Hawaii- 2, Bahamas-1, and British West Indies-1.

If the second buy is approved, the en route beacon system will be homogeneous with Mode S data link capability and coverage down to 6000 feet (MSL or EMA). If the second buy is not approved, the en route beacon system will remain very similar to the existing system with only 25 Mode S replacements for the en route ATCBI sites.

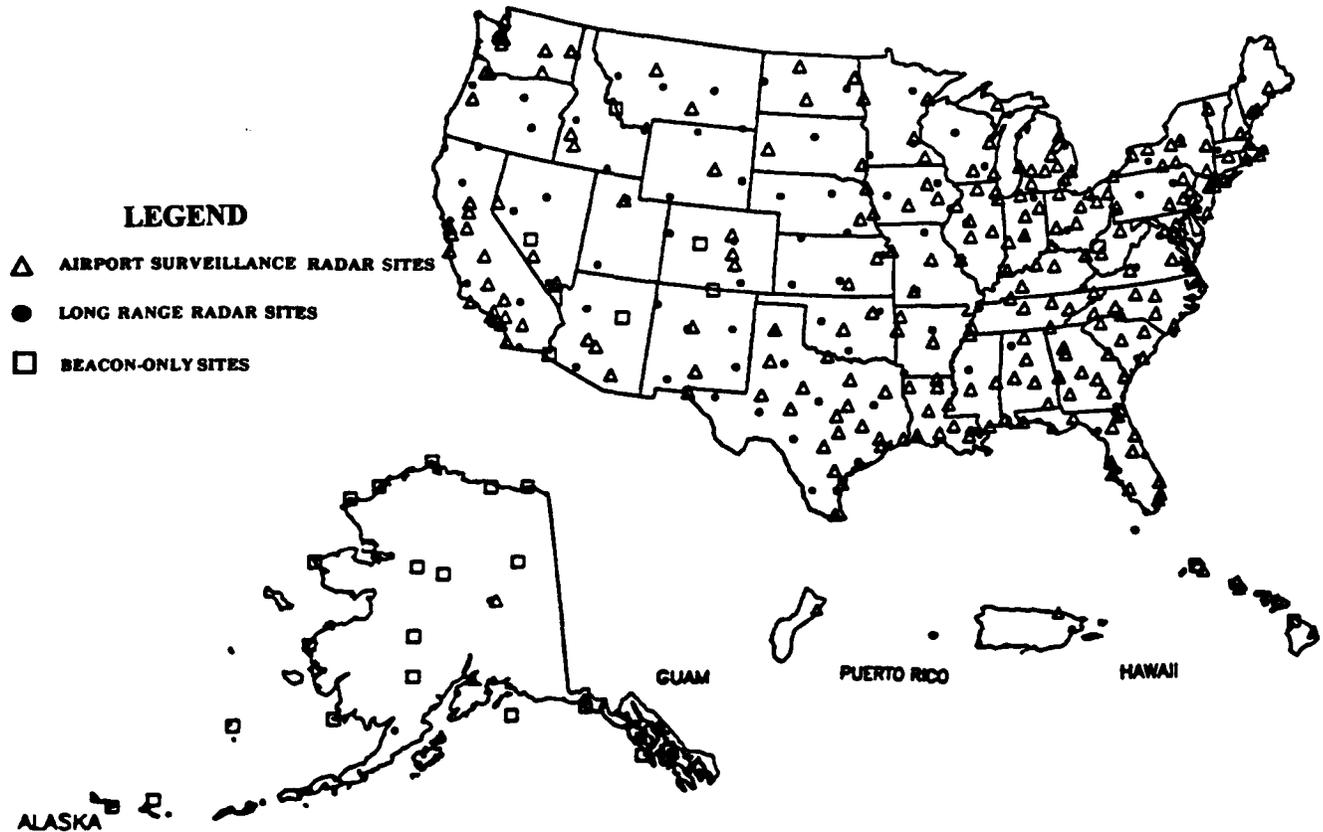
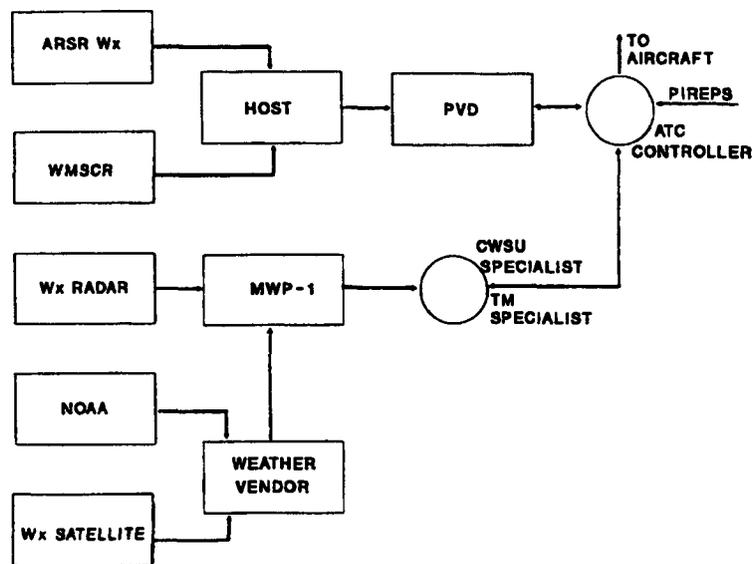


Figure 2-8. NAS Radar Beacon System Sites

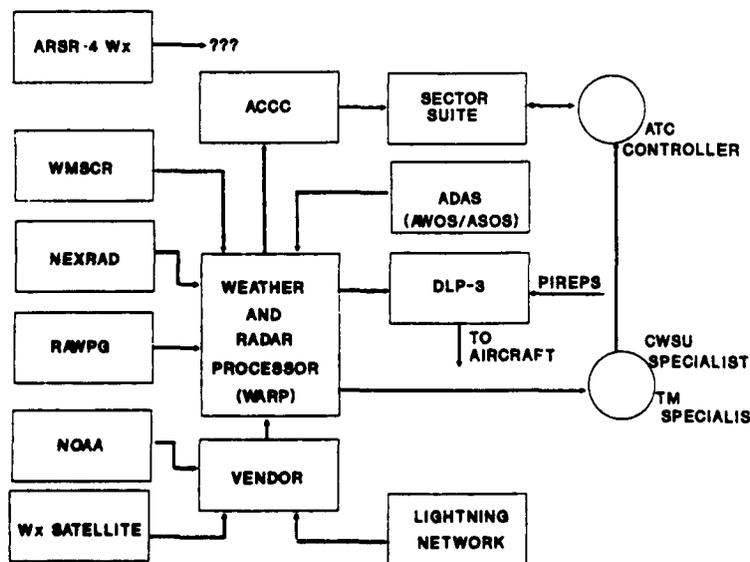
Considering the uncertainties associated with the second Mode S buy and 25 scheduled replacements for the existing en route beacons from the first buy, the en route beacon location and coverage charts will remain essentially identical to the present system.

2.2.2 En Route Weather Surveillance System Planned Evolution

The evolution of the en route weather surveillance system will perhaps be the most dramatic over the time period of interest. The planned evolution consists of the following major elements for the architecture of the en route weather system for 1998 and for 2005 as presented in Figure 2-9.



1998 Architecture



2005 Architecture

Figure 2-9. Weather System Evolution

The major elements of the planned evolution are:

- Implementation of the Weather and Radar Processor (WARP);
- Implementation of the National Weather Products Generator (AWPG);
- Introduction of the DLP-2 and DLP-3.

The figure shows that the planned weather architecture for 1998 remains relatively unchanged as compared to the present architecture. The addition of the DLP-2 to provide weather information in the cockpit via data link is the major feature. AWOS, ASOS, and lightning information will be provided through the ADAS to the DLP.

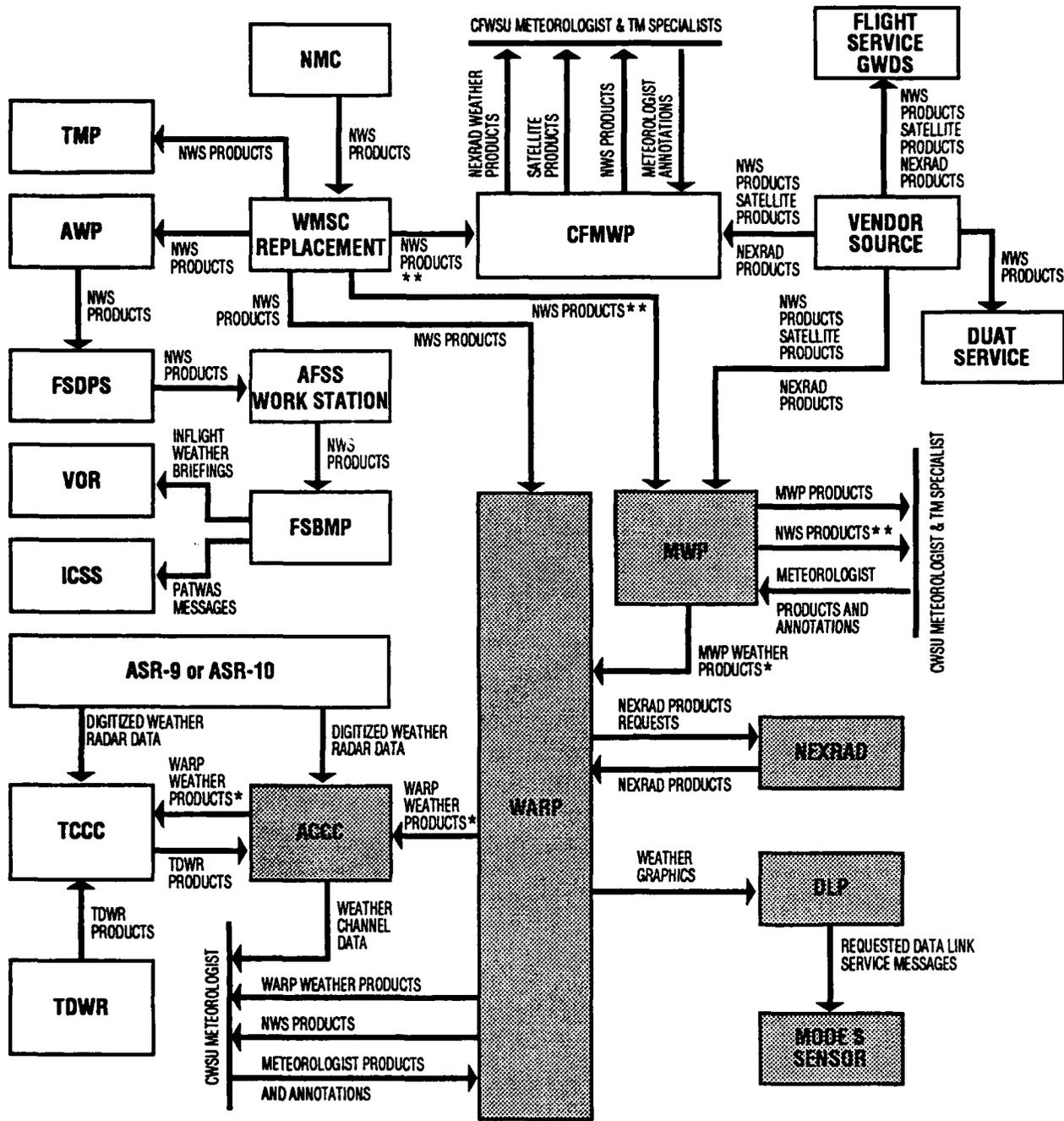
The major change in the planned weather system architecture will occur in the 2005 time frame. At that time, the WARP, NEXRAD, ACCC, and the new Sector Suites (consisting of the Common Consoles) will be implemented and improved weather products will be available to the controller. These products will include icing contours, windshear, thunderstorms, microbursts, and highly accurate multi-level precipitation contours. Earlier availability (year 2000) of NEXRAD reflectivity weather products to the controllers will be accomplished by interfacing the NEXRAD to the WARP and to the ISSS. The interface with the FSDPS must also accommodate the NEXRAD products. A major question however concerning the disposition of the ARSR-4 weather information remains. There appears to be no plan for its use in the system as seen in Figure 2-10⁷. Also, note that data link weather information to the pilot in 2005 replaces controller voice advisories.

2.2.3 Planned System Status

A number of modernization programs involving the evolution of the enroute surveillance system existed prior to the FAA's LRR deactivation decision and must either be modified or terminated to be consistent with it. A concise description of these programs including budgeted funds⁸ and the planned activity period is provided in Table 2-4. These programs require detailed review to determine the potential impact of the FAA decision on their future.

⁷NAS-DD-1000 Radar, Satellite, and National Weather Service Data Flow Diagram, Figure 3-4 (p. III-20).

⁸Budget information was supplied by Diane Essig-Hooper, APM-130; Roger Famiglietti, Mark Clark, and Lewis Fisher, Martin Marietta.



* INCLUDES METEOROLOGIST GENERATED PRODUCTS

** PRODUCTS GENERATED AT NWS FIELD OFFICES

Figure 2-10. Radar, Satellite, and National Weather Service Weather Data Flow

Table 2-4. CIP Active Programs

1.	CIP 21-03 \$0/45.0M* (Total 82-2002)	DARC-Direct Access Radar Channel; Phase II implementation includes automatic track initiation, mosaicing, and real-time quality control. DARC will provide backup for periods of transition to ISSS and AAS. Improved weather display capability will require DARC software modification.
2.	CIP 21-12 ACF/23 Centers \$2,413.1/ 4,703.4M	AAS advanced automation system for <i>transition</i> to ACFs to consolidate ARTCC, ATCT, New York TRACON, implemented in 5 steps: Step 1. PAMRI will support ISSS transition; Step 2. ISSS installed in the twenty modified ARTCC facilities served by the HOST computer; Step 3. TAAS installation for TRACON; Step 4. TCCC installation in tower; Step 5. Evolution of full AAS by addition of software in ACFs to convert the ARTCC into ACFs with the hardware/software known as ACCC (funding has been suspended). ISSS implementation schedule by 1998.
3.	CIP 24-12 \$35.0/438.2M	Procurement of 137 Mode S radars; 108 for the terminal radars at a rate of 48 systems per year. Will provide 56 Mode S back-to-back monopulse antennas; 13 shelters; 41 new and 34 modified rotary joints. Provides coverage to 12,500 feet. Program ends by end of 1995.
4.	CIP 24-15 \$90.1/515.7M	Long-range radar program: 42 ARSRs; 10 ARSR-3 leapfrog reallocations program has been canceled indefinitely; Long-range radar reallocations as required; 76 upgraded enroute tube-type radars. Completion date: 1997
5.	CIP 24-16 \$124.0/374.7M	Installation of new Doppler weather radar (NEXRAD). Completion date: August 1997.
6.	CIP 25-03/ 45-06 \$30.0/313.3M	RML Replacement and Expansion: issues related to microwave link between ARSR and ARTCC or ACFs.
7.	CIP 26-01, 46-01 \$87.6/364.7M	Implement, improve, and sustain modern RMMS. Completion date: 1996/2002.
8.	CIP 34-20 \$180.0/180.0M	Surveillance system enhancement: Implement integrated radar beacon tracker (IRBT) for ARSR-4, ARSR-3 interface with Mode S. Completion date: 2001.
9.	CIP 41-21 \$112.1/162.0M	Software development for 3-level weather contours and display. Implementation by 2000.

Table 2-4: CIP Active Programs (Continued)

10.	CIP 43-02 \$83.0/83.0M	Combined Weather and Radar Processor (WARP): composed of RWP and MWP to provide time-critical information on hazardous and operationally significant non-hazardous weather. Through interfaces to the DLP, RWP will supply products for uplink to pilots via Mode S and receive aircraft-based winds and temperature. Implementation scheduled by 1998.
11.	CIP 44-39 \$5.0/5.0M	Relocate long-range radars to improve air space coverage: 2 sites per year. Projected activity time: up to 1995.
12.	CIP 44-40 \$28.2/30.1M	ARSR improvements to carry for additional 15 years: transmitter upgrade (the MNS for the transmitter upgrade was withdrawn/canceled); radar set control, rotary joints, APGs, etc.; clean cable trays; improve facility grounding; Solid-State Transmitter development. Improvements scheduled for completion by 1997.
13.	CIP 44-42 \$29.0/50.4M	Long-range radar radome replacement: work to be completed in three phases - Phase I - 26 radomes; Phase II- 10 radomes; Phase III - 74 radomes. Work to be completed by 1996.
14.	CIP 44-43 \$5.5/0.65M	Radar pedestal vibration analysis will only need \$650,000 of the 5.5M. The remaining 4.85M will be used for other LRR-related activities.
15.	CIP 44-45 \$6.1/7.1M	ATCBI-5, 52 systems; ATCBI-4, 44 systems; RBPM, 96 systems; to be relocated after Mode S procurement is completed (first buy). Implementation span up to 1994.
16.	CIP 44-46 \$916.1/916.1M	ATCBI replacement by Mode S, and data link services with the second buy. Completion date is the year 2002 +.
17.	CIP 46-08 \$329.0/349.0M	Modernize and Improve FAA Buildings and Equipment. This program requires review in light of FAA deactivation decision.
18.	CIP 56-17 \$232.0/245.0M	System Support Laboratory Sustained Support. The program parts related to en route systems and maintenance and operations support systems will require a review in light of FAA deactivation decision.
19.	CIP 56-27 \$39.2/46.4M	Test Equipment Modernization
20.	CIP 56-41 \$2.9/4.8M	Development of enhanced radar analysis tool for Mode S and other JSS radars.
21.	CIP 56-53 \$2.0/2.0M	This project has 2M in FY-93 Funds and will be used to retrieve parts from military radars to support operational radars. At this time no additional funds are being sought.
22.	CIP 61-22 \$4.2/32.0M	ATC Application of Automatic Dependent Surveillance (ADS).

Table 2-4: CIP Active Programs (Continued)

23.	CIP 63-22 \$88.9/103.9 M	AWPG- Aviation Weather Products Generator: will integrate all NAS/FAA weather sensor data into real-time weather products for use by aviation community; will store the gridded database, generate aviation user special graphic and alphanumeric weather forecast products, and generate voice aviation messages. Completion date by 1999. This will provide software enhancement to WARP.
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Total: \$2.4B/\$4.3B* not including CIP 21-12 program of AAS \$2.4B/4.7B.

*CIP steering committee approved partial financial baseline 21 June 1993 for time period up to the year 2002
(Funds approved for the time period 1994 to 2002/Total funds approved and already spent between the years 1982-2002)

2.3 FUTURE SYSTEM EVOLUTION AND REQUIREMENTS ANALYSIS

This section presents the derivation of the en route surveillance system requirements necessary to support the FAA decision to deactivate the long-range radars. The process consists first of defining the future en route surveillance system architecture that will result from deactivation. Once this future architecture is established, impacts on existing systems and programs will be analyzed. Programs to be examined include:

- CIP Programs
- R, E&D Programs
- Ops Programs
- Training Programs
- Personnel Programs
- Maintenance Programs

The compilation of this information will be used to determine the need for new program initiatives (NPI) and modifications to existing programs required to implement the deactivation decision. This work includes consideration of requirements for:

- Stand-alone Beacon Radars
- Military and Law Enforcement Border Surveillance
- Decommissioned Dual Site Operation
- Coverage (Terminal and En Route)
- Weather Products (includes NEXRAD Processing)
- ARSR-4 Wx Products
- En Route Gap-fillers
- New Terminal Radars
- Rotary Joint Modifications
- Antenna and Electronics Upgrades

2.3.1 Future En Route Surveillance System Architecture Definition

Recall the key assumptions in Section 1 that affect the architecture of the post-deactivation decision en route surveillance system:

1. Maintain or improve existing weather products, quality and timeliness;
2. Maintain or improve existing aircraft surveillance performance;
3. IFR flights and VFR aircraft flying above 6000 feet will be transponder-equipped;
4. NEXRAD products will be available to the controllers by the year 2000;
5. JSS sites will be maintained and ARSR-4 will be deployed.

The architectures for aircraft and weather surveillance systems resulting from these five assumptions are described in the following subsections.

2.3.1.1 En Route Aircraft Surveillance System Architecture

Assumptions 2, 3, and 5 pertain to aircraft surveillance and imply the following:

- Beacon system performance and coverage after deactivation must be at least as good as the combined primary/secondary system before deactivation;
- Beacon system coverage is required down to 6000 feet;
- A sufficient number of LRRs must remain to satisfy the law enforcement and national defense requirements.

Thus, the planned beacon system architecture consisting of the first and second buy of Mode S sensors will satisfy the requirement for beacon coverage down to 6000 feet. With the first Mode S buy only, coverage in all en route airspace above 6000 feet MSL (or minimum IFR enroute altitude and above whichever is higher) cannot be achieved with the remaining ATCBI-4 and -5 systems without site relocations and additional gap-fillers. In addition, coverage above 6000 feet requires both terminal and en route beacons so that terminal beacon data must be transmitted to appropriate ARTCCs.

2.3.1.2 En Route Weather Surveillance System Architecture

Assumptions 1 and 4 pertain to weather surveillance and imply the following:

- The distribution of the NEXRAD weather radars will provide weather coverage equal to or better than present ARSR weather coverage;

- The accuracy and resolution of the NEXRAD⁹ weather products will be equal to or better than the present ARSR products:
- The latency of the data will not adversely impact tactical use of the information.

Based on the planned weather system architecture (Figure 2-9), weather support to en route operations is dependent on the availability of NEXRAD, WARP, and ACCC or a suitable interface with the ISSS. Two types of weather products are planned: real-time products and forecasted products. The real-time products consist of Doppler and reflectivity products including hail, rain, snow, gust fronts, and windshear. The forecasted products include storm forecasts, clear air turbulence (CAT), icing, winds/temperature aloft, and cloud tops/bases. The future system will display these products to the en route controller on an integrated weather/target display.

The baseline products provide a substantial improvement over the present en route weather capabilities. The Martin Marietta¹⁰ study concluded that the desirable tactical weather product goals would be as shown in Table 2-5.

Table 2-5. Target Tactical Product Goals

SIGNIFICANT WEATHER ELEMENT	UPDATE TIMING (min)	ACCURATE FORECAST TIME (min)	HORIZONTAL RESOLUTION (Km)	VERTICAL RESOLUTION (m)	SEVERITY
TURBULENCE	1	30	5	300	NORMALIZED INDEX (NCAR)
ICING	2	30	5	300	SEV., MOD., LT.
THUNDERSTORMS	1	10	2	300	SEV., MOD.
TORNADOES	1	10	2	-	SCALE 1-5
MESOSCALE STORMS	1	10	2	300	
HEAVY RAIN OR HAIL	1	10-20	2-4	300	
CLOUD TOPS (OR ECHO TOPS)	2	10	2-4	300	-

ASSUMES: ▾ PROBABILITY OF DETECTION OF 95%
 ▾ A FORECAST PROBABILITY OF AT LEAST 90% THAT WITHIN THE FORECAST TIME THE BOUNDARIES OF THE HAZARDOUS VOLUME WILL BE WITHIN THE SPECIFIED RESOLUTION

⁹Data provided by Doran Platt, National Weather Joint Programs Office, Silver Spring, Maryland.

¹⁰Design Working Group presentation, En Route Weather Study, Washington D.C., 5 March 1992., SEIC.

These goals are not critical for the implementation of the deactivation decision by the year 2000. The coverage, accuracy, and resolution of the NEXRAD products is, in general, superior to that provided by the ARSR system. However, the currency of the tactical weather products may not meet user needs (6-minute data latency for the full spiral scan) since the NAS-SR-1000 requirement explicitly states that hazardous weather information shall be available to the controller within 2 minutes of identification and shall be distributed locally within 2 minutes.

The planned distribution of the 154 NEXRAD¹¹ systems is shown in Figure 2-11 and distributed as follows:

CONUS	139
Alaska, Guam, Hawaii	15
Total	154

The NEXRAD has been jointly developed by the FAA, DOD and DOC and ownership of the 154 NEXRAD systems is as follows:

FAA	16
DOD	29
NWS	109
Total	154

The predicted NEXRAD coverage¹² to provide weather information at 10,000 feet and above is based on the site locations as provided in Figure 2-11. Coverage charts for the NEXRAD sites are provided in Appendix E. NEXRAD installation and checkout is scheduled for August 1996 completion.

The schedule for the ISSS interface indicates that the installations at the ARTCC will begin in October 1996 and end by December 1998. The WARP will follow the ISSS by approximately one year, with an estimated completion date of December 1999. Thus, it is possible that NEXRAD products will be available for the controller by January 2000, although certain concerns must be addressed including:

- How does the WARP interface with the ISSS?
- Will controllers accept the 6-minute NEXRAD data latency?

¹¹The NAS-SS-1000 lists 151 NEXRAD radars. The 154 installations are listed in the latest NEXRAD delivery schedule, Modification 0182, Section F, Rev. 8/2/93.

¹²NAS Plan, September 1989, page IV-30.

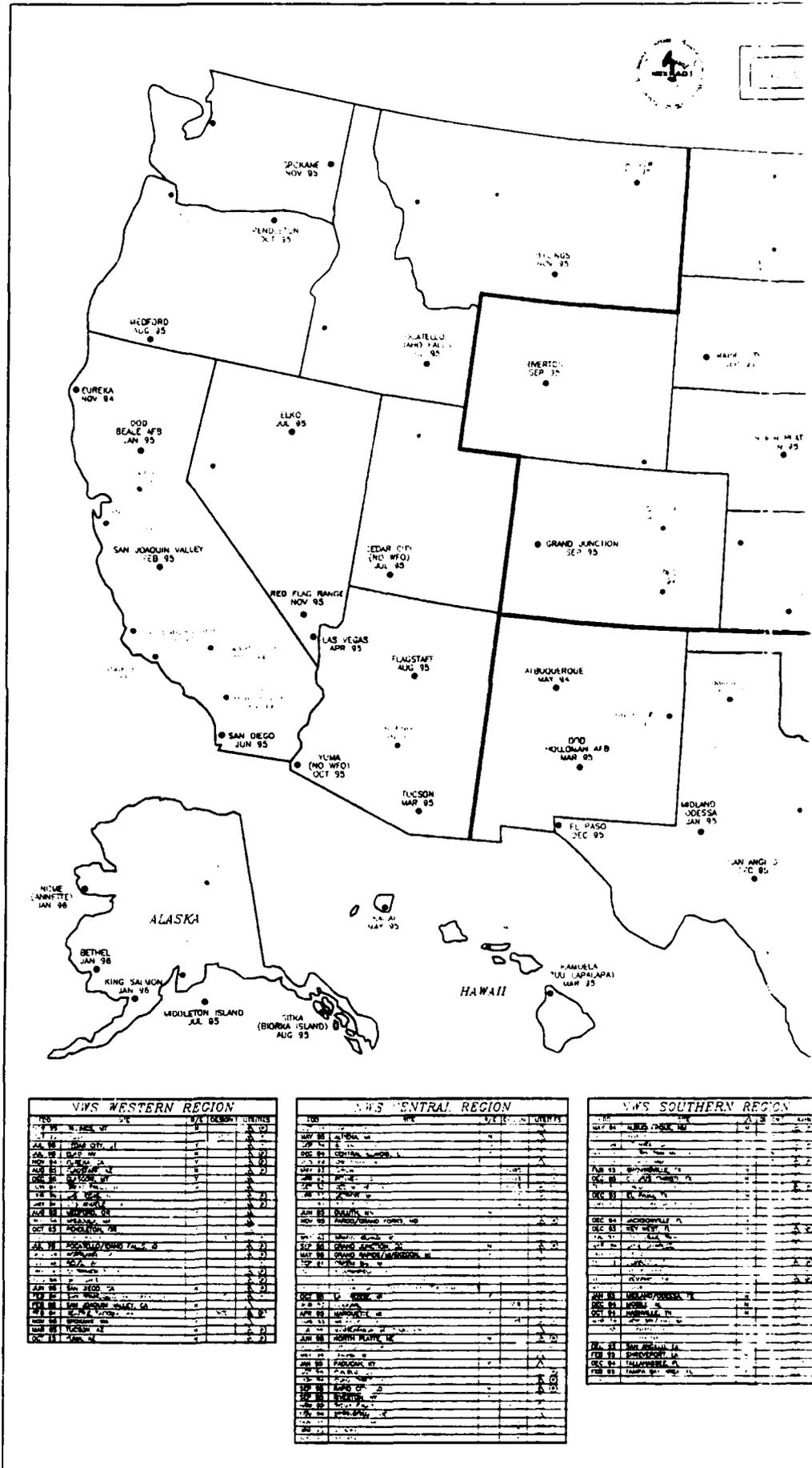
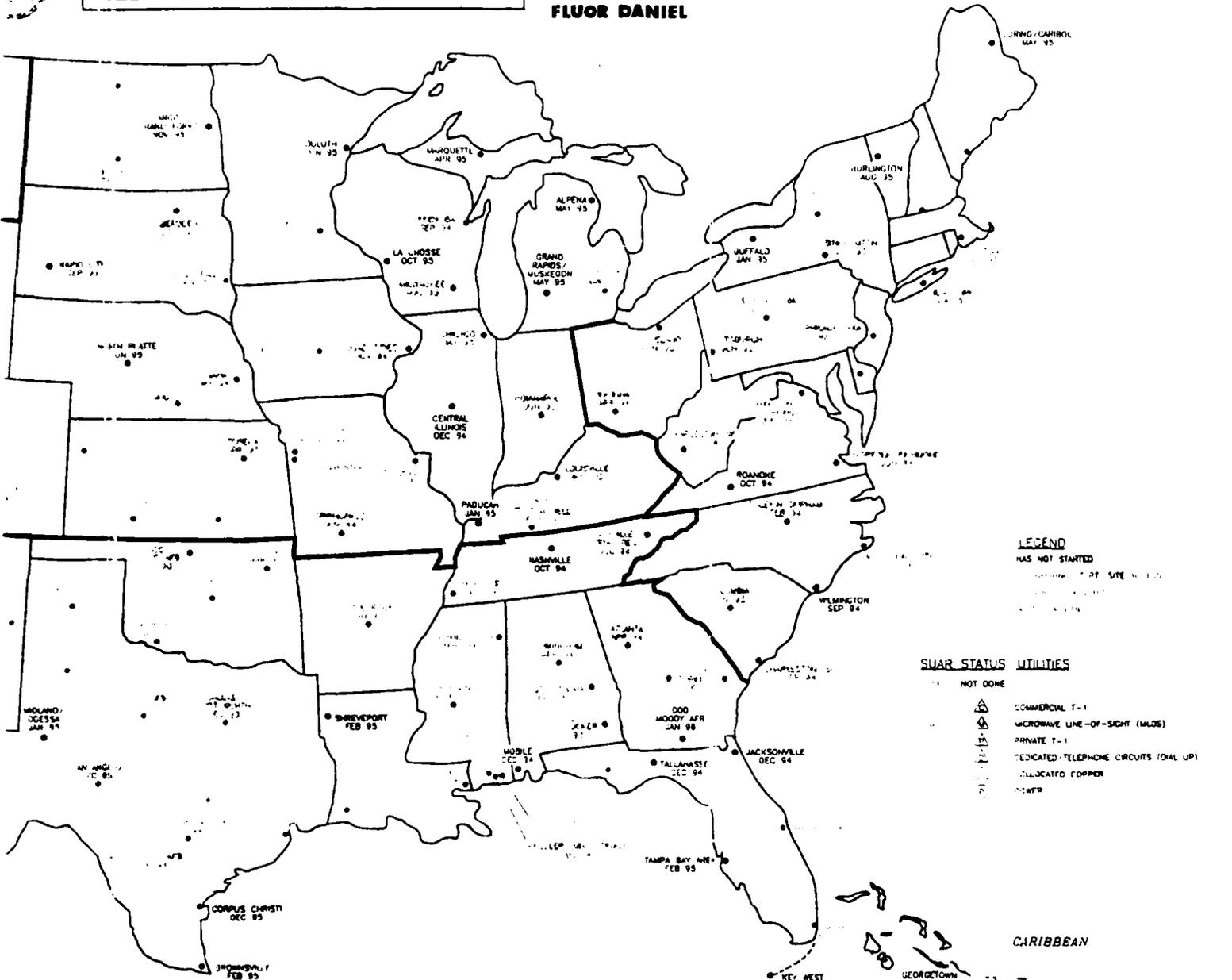


Figure 2-11. NEXRAD Site Locations



SENTRAD RADAR SITE FACILITIES STATUS



LEGEND
HAS NOT STARTED
SITE NOT YET
CONSTRUCTION
SITE NOT YET

SWAR STATUS UTILITIES
NOT DONE
COMMERCIAL T-1
MICROWAVE LINE-OF-SIGHT (MLOS)
PRIVATE T-1
DEDICATED TELEPHONE CIRCUITS (DIAL UP)
DEDICATED COPPER
POWER

SOUTHERN REGION

Site Name	Status
MOBILE	...
...	...

MIDWESTERN REGION

Site Name	Status
...	...
...	...

FLA

Site Name	Status
...	...
...	...

LUD

Site Name	Status
...	...
...	...

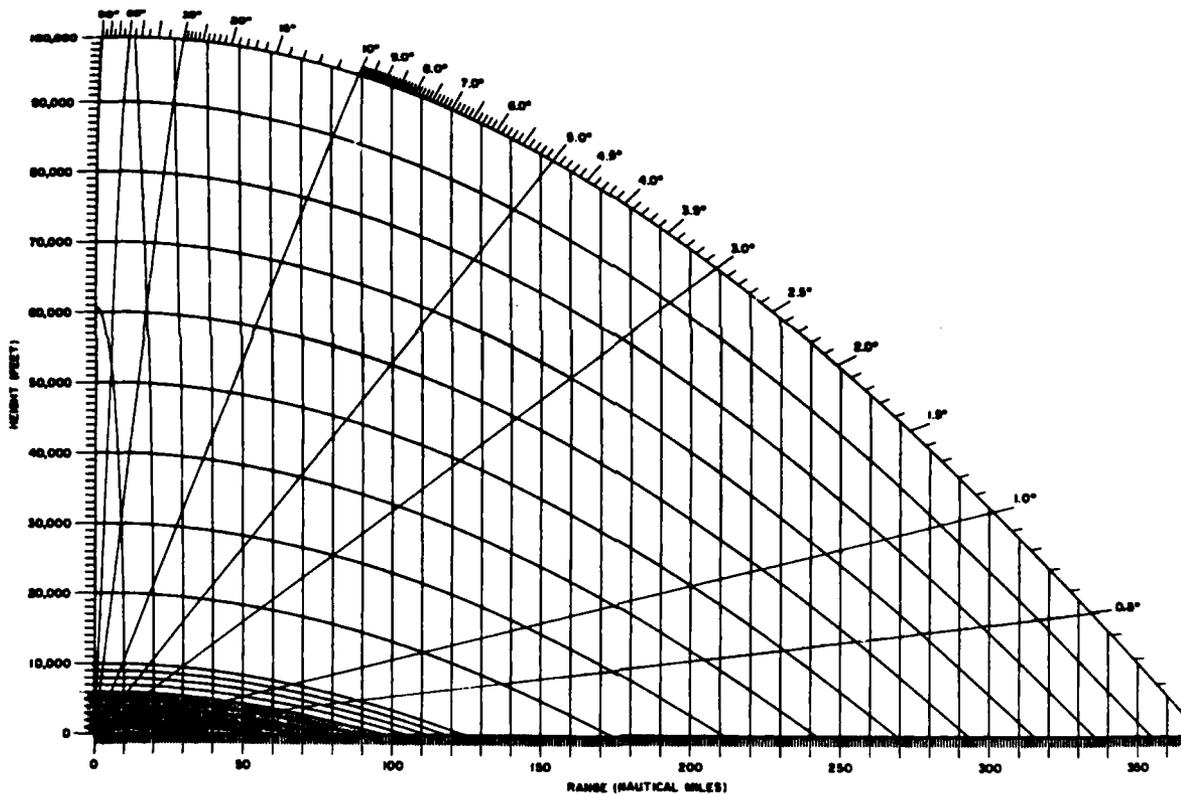


PACIFIC
MEDITERRANEAN
AZORES AFB AZORES (JUL 95)

2.3.1.3 Comments on Differences Between the NEXRAD and LRR Weather Coverage

The 6000 feet altitude coverage ranges for NEXRAD and LRRs are dramatically different as shown in Figure 4-1 and Appendix E. The reason for the differences is the restricted elevation angle for the antenna beam for the NEXRAD at plus 0.5 degrees from the horizon. This effect is illustrated in two steps: first by deriving radar range and then considering the effect of +0.5 degree minimum elevation.

Figure 2-12 is a classical radar coverage chart used to predict radar range based on atmospheric defraction effects. The chart provides information on radar coverage range vs. altitude of the target to be observed. The maximum coverage range is 100 nm for coverage altitude of 6000 feet and above. The shaded area in the chart illustrates the future 6000 feet altitude coverage requirement.



Source: L. V. Blake, "Radio Ray (Radar) Range-Height-Angle Charts," Naval Research Laboratory Report (1968).

Figure 2-12. Radar Range-Height-Angle Chart

Figure 2-13 illustrates why there is so much difference in the coverage ranges between the two radars. The reason is that the antenna boresight pointing angle is restricted to 0.5° above the horizon. Therefore, the effective radar range for 6000 feet target altitude is not achievable at 100 nm because target is below radar coverage. At +0.5° above the horizon and accounting for earth curvature, 6000 feet target altitude occurs at approximately 70 nm as illustrated in Figure 2-13.

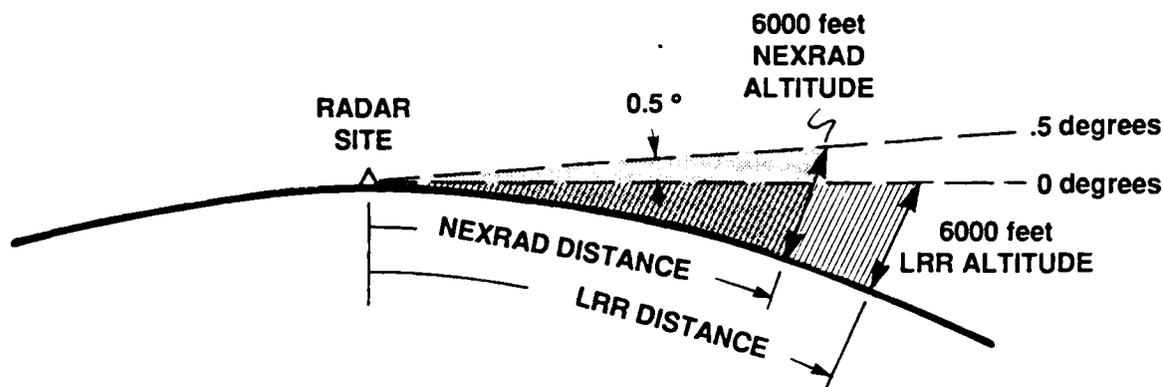


Figure 2-13. NEXRAD Effective Coverage Range

2.3.2 Program Impacts

Several existing and planned programs in the F&E, R, E&D and Operations appropriations will be impacted by FAA's LRR deactivation decision. The following subsections identify the affected programs in each of the appropriations and provide recommended actions to effectively and efficiently implement the deactivation decision.

2.3.2.1 F&E Appropriation Programs

The following F&E programs in the Capital Investment Plan are affected by the deactivation decision.

21-03 Direct Access Radar Channel (DARC) System: Examine to determine required software modifications for weather display capability and for beacon-only operation.

21-06 Traffic Management System: Examine the planned weather system interfaces to determine the impact of ARSR Weather being replaced by NEXRAD.

21-12 Advanced Automation System (AAS): Software modifications in the ISSS and ACCC may be necessary to accommodate beacon-only operations (e.g., target correlation and tracking).

23-02 Central Weather Processor (CWP): The RWP element of the program is affected by the potential requirement for an interface with the ISSS. It must also be expanded to include the examination of new NEXRAD scanning strategies, multi-radar coverage and processing, weather radar data fusion, and other methods to reduce the 6-minute latency problem. CWP is to be replaced by WARP.

24-12 Mode S: The Mode S second buy should be reexamined in light of the decision to deactivate the LRRs and the requirement for beacon coverage above 6000 feet.

24-15 Long-Range Radar Program: Elements of this program need to be modified or deleted. These include the upgrade of the tube-type LRRs and the previously planned relocations. The program related to ARSR-3 Leapfrog reallocations has been canceled indefinitely. Since this program will provide necessary replacements for the antiquated systems, emphasis should be placed on the need for reinstatement.

24-16 Weather Radar Program: While this program focuses on the procurement of the NEXRAD radars, it must be expanded to include the examination of new scanning strategies, multi-radar coverage and processing, and other methods of reducing the 6-minute latency problem.

25-03 RML Replacement and Expansion: The radar microwave link will no longer be required to provide communications for broadband data from sites. The implications of this change in requirements on the new RCL backbone should be examined.

26-01; (46-01) Remote Maintenance Monitoring System (RMMS): Modifications to software and possibly hardware must be made to accommodate the decision to deactivate the LRRs.

26-07 Power Systems: Plans for modernization of ARSR facilities whose LRRs will be deactivated should be reviewed. Some modernization may be required during the interim period of operation. 1994 to 2002 or even to 2008.

26-17 System Support Laboratory: Those elements of the simulation facilities at the FAA Technical Center that are related to the LRRs must be examined for needed modifications.

34-20 Surveillance System Enhancements: The integrated Radar Beacon tracker for primary and Mode S radars should be reexamined relative to the LRRs. The need should also be looked at relative to the ASRs since this correlation and tracking is also performed at the ARTCC and TRACONS.

41-21 En Route Software Development Support: The software impacts of the deactivation decision on the Host computer must be determined and mitigated as part of this program. For example, the en route software may have to be modified to accept terminal beacon radar data.

43-02 Combined Weather and Radar Processor (WARP): composed of RWP and MWP to provide time-critical information on hazardous and operationally significant non-hazardous weather is critical to meet 2002 schedule.

44-39 Sustain/Relocate Air Route Surveillance Radar (ARSR): This program is severely impacted by the decision and by the ARSR-3 Leapfrog Program indefinite hold; therefore, it must be totally replanned.

44-40 Long-Range Radar Improvements: This program is severely impacted by the decision and by the ARSR-3 Leapfrog Program indefinite hold; therefore, it must be totally replanned.

44-42 Long-Range Radar Radome Replacement: This program is severely impacted by the decision and must be totally replanned. Under the current plan contract options will be exercised to replace radomes at as many as 84 additional en route facilities.

44-43 Radar Pedestal Vibration Analysis: This program is important for all en route facilities.

44-45 ATCRBS Relocation: Relocation must be reexamined for 6000-foot coverage with and without the Mode S second buy. Depending on these location requirements, this program should be replanned.

44-46 ATCBI Replacement: Replan based on 6000-foot coverage requirements.

46-08 Modernize and Improve FAA Buildings and Equipment Sustained Support: Replan based on the deactivated LRRs.

56-17 System Support Laboratory Sustained Support: Eliminate planned support involving LRRs.

56-27 Test Equipment Modernization and Replacement: Eliminate planned modernization and replacement of LRR test equipment.

56-29 On-site Simulation-Based Training Systems: Eliminate elements associated with the LRR simulation requirements.

56-41 Development of an Enhanced Radar Analysis Tool: A single integrated tool for analyses of Mode S, ARSR-4, AN/FPS-117, and others.

56-53 This project has 2M in FY-93 Funds and will be used to retrieve parts from military radars to support operational radars. At this time no additional funds are being sought.

61-22 ATC Applications of Automatic Dependent Surveillance (ADS): This program should be accelerated for CONUS to provide a backup to the enroute beacon system once the LRRs are deactivated.

63-02 Central Weather Processor (CWP) Interfaces: Modify this program to include the WARP/ISSS interface issue.

63-20 Weather Enhancements: Add scanning strategy algorithms to the NEXRAD portion of this program. Use this program to investigate alternative solutions to the 6-minute latency issue.

63-22 Aviation Weather Products Generator (AWPG): This program should be modified to be a WARP enhancement program.

2.3.2.2 R, E&D Appropriation Programs

The R, E&D programs affected by the FAA's LRR deactivation decision are discussed below.

021-150 ATC Applications of Automatic Dependent Surveillance (ADS): This program should be examined to better define the purposes for which ADS would be used. If it is to provide a backup to the en route beacon system once the LRRs are deactivated, thereby adding back the margin of safety lost due to beacon system failures, then it should be modified to eliminate the transponder as a common failure point, or it should only backup the beacon radar ground equipment.

041-110 Aviation Weather Analysis and Forecasting: Add scanning strategy algorithms to the NEXRAD portion of this program. Use this program to investigate alternative solutions to the 6-minute latency issue.

2.3.2.3 Operations Appropriation Programs

Operations programs related to the FAA deactivation decision include:

- Controller and maintenance specialist hiring and training programs. For example, ARSR-1 and -2 maintenance would no longer be required. Training related to the use of ARSR weather products should also be reviewed in depth.
- Funding to continue primary LRR operations for at least 6 years and possibly 10 years.
- Logistics, spares and site/depot maintenance programs relating to the deactivated LRRs.
- Operations personnel requirements related to maintaining the deactivated radars.

2.3.3 Deactivation Decision Support Requirements

The FAA's LRR deactivation decision will result in the evolution of the present primary/secondary surveillance system into a beacon-only system with JSS primary radars retained for border surveillance. The actual evolutionary path that will be taken is highly

dependent on the Mode S second buy decision and the eventual role of the ADS system in en route domestic airspace.

The following new programs must be initiated in order to change over from the existing system to the future beacon system with NEXRAD providing the weather radar function.

2.3.3.1 Primary Radar Site Cleanup

Up to 78 FAA primary/search radar sites are affected by either being modified for beacon-only operation or completely decommissioned. This modification can be accomplished in a variety of ways. At one extreme, the primary radar is simply electrically disconnected. At the other extreme, all primary equipment is removed, the site is relocated, and new beacon elements including antennas, rotary joints and the like are installed.

A site cleanup of hazardous materials will remain a formidable task.

2.3.3.2 Mode S System Development

This program is focused on the design and development of a Mode S beacon-only system. This design can range from a Mode S with full data link capability and a phased array antenna compatible with the ADS and squitter mode, to a simple Mode S beacon surveillance-only system. Site locations/relocations must also be investigated to satisfy the 6000-foot coverage requirement. Potential extension of the range of the terminal beacon radars to 100 nm and interface with the ARTCC may be required.

2.3.3.3 Stand-Alone En Route Beacon System Design

In the event that the decision is made not to continue with the Mode S, a beacon system compatible with ATCRBS and Mode S must be designed for en route operations. This design includes antennas, pedestal, rotary joint, tower, beacon system and all beacon radar elements such as shelters, etc. Site locations/relocations must also be investigated to satisfy the 6000-foot coverage requirement. The impact of Mode S data link limitations to transmit weather data must be evaluated.

A redesigned en route beacon antenna without radome will permit operation at a 5-to-6-second scan rate. This could provide major improvements in tracking and reduce site costs, but would also necessitate examination of hardware interfaces and software to accommodate the higher data rate.

3. TRANSITION/IMPLEMENTATION PLANS TO REALIZE FAA'S DECISION

The deactivation of the primary radars will initiate a new phase of the surveillance service in the en route environment. The decision will not affect the new ARSR-4s which will be located on the perimeter of the CONUS and which also provide air defense and drug interdiction data as part of the FAA/DOD Joint Surveillance System (JSS). Locations where primary radar is removed could become beacon-only sites, and be upgraded to Mode S according to current schedules.

This section addresses the en route surveillance system transition from the primary/secondary radar to beacon-only system. The transition strategy, implementation guidelines, resources, schedules, and program requirements are discussed. In developing the transition plan, it was recognized (Table 2-4) that the beacon-only architecture presently being developed as a result of the deactivation decision may become an interim system. It will replace the existing independent (ground-based) system and could be replaced by a dependent (satellite-based) surveillance system between 2015 and 2030. In considering the transition to the beacon-only architecture, one must address the following areas:

1. En Route Radar Coverage: Implementation of the 6000-foot altitude coverage specified in NAS-SS-1000 and the Decision Memorandum, will restrict the radar line-of-sight coverage range to 100 nm at many sites. Therefore, it may be necessary to install a number of new beacon sites and to relocate certain existing sites. The Mode S second buy is intended to satisfy this coverage requirement.

2. Beacon Antenna: Use of a single Mode S open array design antenna without a radome is planned except in areas of severe wind, snow and icing conditions. In the terminal environment, the open array is designed to withstand up to 1-inch-diameter hailstones. It will operate in 86 knot wind gust with 1/2-inch radial ice, and will withstand 100 knots with 1/2-inch radial ice in non-operating state. The analysis and impact of loading of the open array without radome was evaluated in the past by the FAA.¹ The open array is designed for maximum rotation rate at 17 rpm.

A single monopulse open array antenna similar to the ASR-9 site at Salt Lake City, UT, already exists in the FAA inventory and operates without a radome. When modified with a cosecant-square beam pattern in elevation, improved beam pointing at lower angles is achieved with higher cutoff at 100 nm range. Thus, a faster rotation rate that will satisfy target update rate requirements can be realized for en route. This approach eliminates the need for the back-to-back beacon antenna design currently planned for en route systems.

3. Weather Products: The statement in the Decision Memorandum "...when NEXRAD products are provided to the controller" is subject to interpretation. There are two levels of NEXRAD products planned. The first set of products is similar to those available from the ARSR-4 and provides multilevel weather reflectivity information to the

¹Janis Vilcans, Test Plan for SSR Antenna Rotation Rate Stabilization: DOT/FAA/RD-81-64.

controller. The second type is more ambitious and involves weather modeling, forecasting and algorithm development. The determination of which set of products is required for primary radar LRR deactivation will fix the initial starting date of the deactivation process. For purposes of this planning effort, it is assumed that the multilevel reflectivity information is what was intended by the Decision Memorandum and even with this assumption, the 6-minute data rate issue must be addressed. Methods must be developed to provide more rapid updating of the composite weather picture, or the en route controllers must accept the weather data latency. Comparative tests are being conducted to determine the potential impact of the 6-minute data latency on aviation safety based on the development and movement of actual storms. An alternate approach is to consider the possible modeling and short-term forecasting of the development and motion of the weather phenomenon and to update the forecast on the basis of 6-minute measurements.

This chapter is organized into two major sections; the first section deals with the transition strategy to be used to evolve to a beacon-only system; and, the second section presents an implementation. Elements of the plan include a work breakdown structure, schedules, and resource estimates.

3.1 PRIMARY-TO-BEACON TRANSITION STRATEGY

The formulation of the transition strategy hinges on the fact that the primary and the beacon radars are collocated and operate synchronously at current LRR sites, but can and are planned to operate asynchronously. The beacon and the primary radar share the same pedestal, rotary joint, APG, primary antenna reflector and the Common Digitizer. Operating together, they use the same trigger initiated in the primary, which assures a continuous synchronism between radar interrogations (this is different than the ARSR-4 radar which operates asynchronously). Thus, strategies ranging from a simple electrical disconnection of the primary radar to removal of the primary components and modification and upgrade of the beacon components is possible. Beacons may need trigger generators if the primary radar triggers are unavailable.

The Mode S operates asynchronously, unlike systems operating now at en route sites. RF interference may occur during asynchronous operation at ARSR-1, -2 sites² because transmitted spectrum emanating from magnetrons and amplitrons is "dirty." Since the radar improvement program for converting magnetron and amplatron transmitters to klystrons was not approved, the Mode S received signal may not be filtered adequately. This type of interference with collocated Mode S will be evaluated at the Elwood, N.J. radar site. If the interference is detected, the system will be operated in the Interim Beacon Interrogator (IBI)³ mode until the problem is resolved.

The issues related to a successful transition from primary to beacon radar are availability of resources, a timely schedule, and a carefully formulated and executed implementation

²Sensis Corporation, Preliminary Analysis of Potential EMI Between Mode S and Existing En Route Radars, January 20, 1992; and, Westinghouse Electric Corporation, Radar/Beacon Mutual Interference Analysis Report for the ARSR-4, August 2, 1991.

³IBI refers to operation in original ATCRBS modes instead of using Mode S.

strategy. This strategy must provide a smooth transition and must be effective and efficient.

In the present system, there is a multiplicity of equipment combinations at the long-range radar sites; therefore, each site must be evaluated separately and deactivation strategy established on a site-by-site basis. To be efficient, an effort to apply the same or a similar top-level strategy across all sites or at a minimum across groups of sites must be made. The deactivation strategy must address the following items:

- Decommissioning Process;
- Ground Equipment Transition;
- Airborne Equipment Transition;
- Site-by-Site Evaluation and Center-by-Center Implementation; and,
- Operational Procedures Development.

Each of these items is separately addressed in the following paragraphs.

3.1.1 Decommissioning Process

The decommissioning process includes the following elements:

- Determining a National Deactivation Schedule;
- Establishing a Beacon-Only Test Plan;
- Conducting Operational Test and Evaluation;
- Defining Integration and Cutover (INCO) Procedures;
- Performing Operational Readiness Demonstrations;
- Maintenance Support/Training; and
- Planning Site Cleanup and Safe Disposal of Hazardous Materials: Asbestos, Waste Oils, Contaminated Fuels, and PCBs⁴.

A deactivation schedule will be prepared for all 78 en route radar sites affected by the decision. This schedule will be reviewed by and concurrence obtained from ANR, ASE, ASM, AOS, ATR, and Regional Managers based on submitted deactivation strategy schedules and site selection criteria.

The schedule dates and criteria for deactivation strategy will be based on consideration of many factors including:

1. The date when the NEXRAD products are available to controllers. This depends on the NEXRAD, ISSS, WARP deliveries, and the display console interface availability at each site;
2. Predicted primary radar life expectancy and equipment status at each site;

⁴PolyChlorinated Biphenyls: Volpe Center Environmental Projects, March 8, 1993.

3. Peak Instantaneous Traffic Counts (PIC)⁵ experienced by and forecasted for each site, as shown in Figure 3-1;
4. ARSR-1, -2 sites with magnetron/amplitron transmitters;
5. FPS Series sites with klystron transmitters;
6. ARSR-3 two-channel radar sites, all of which have a separate weather radar channel;
7. Climatological conditions at each site, as shown in Figure 3-2.⁶

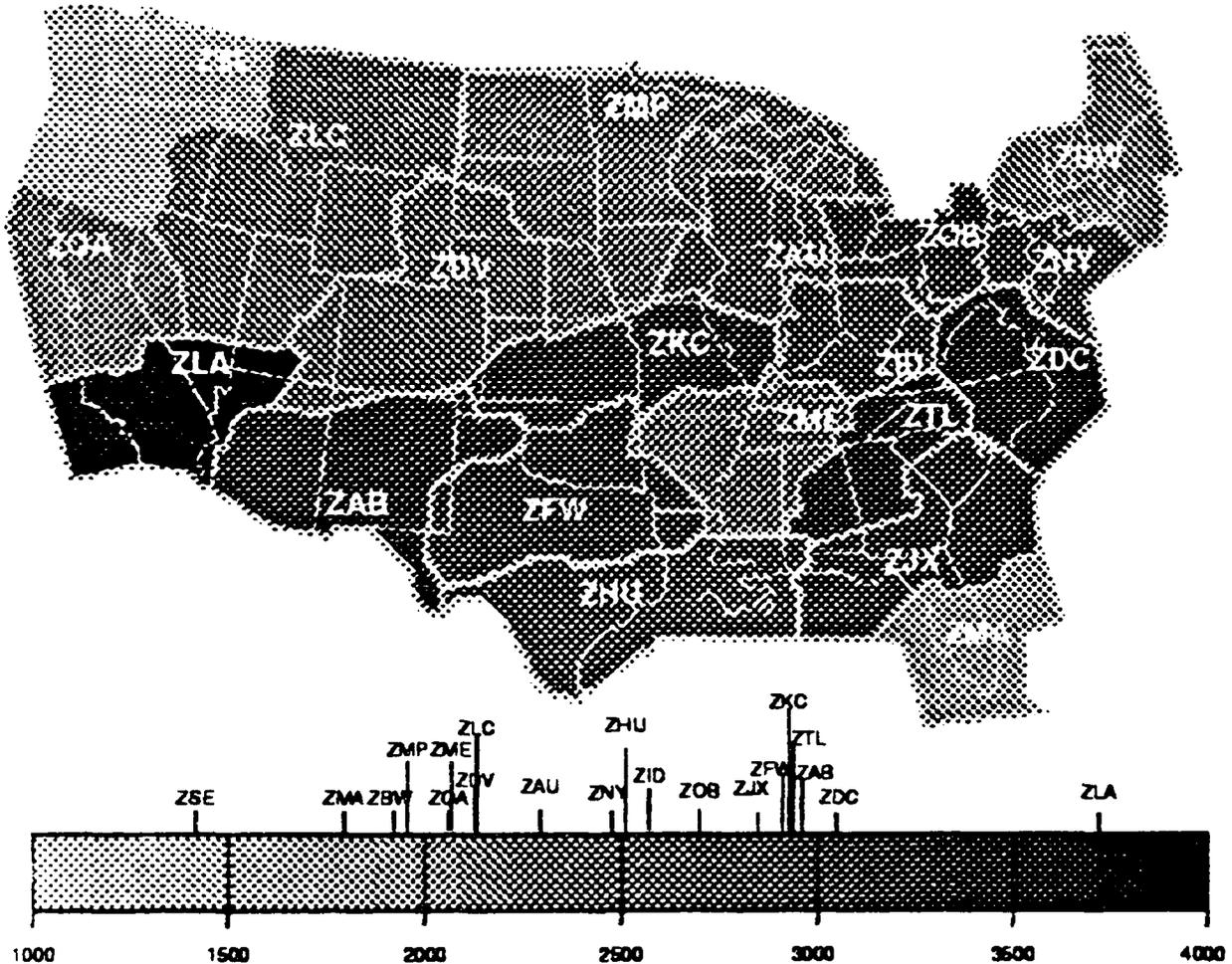


Figure 3-1. Peak Instantaneous Traffic Counts by ACF in 2010

The remaining elements of the decommissioning process constitute a major investment of resources. A beacon-only test plan should be established as soon as possible by the FAA Technical Center in order to evaluate the magnitude of the testing required. Operational Test and Evaluation of beacon-only sites should be initiated at the FAA Technical Center

⁵Braff, Roland; Hershey, William; Hsiao, Thomas; Shively, Curtis; Viets, Karen. RAPSAT: Application of Onboard Processing for Communication and Surveillance in Air Traffic Control, MITRE, March 1990.

⁶Vilcans, Janis; Burnham, D. Climatological Study to Determine the Impact of Icing on the Low Level Windshear Alert System, DOT-TSC-FAA-89-2, September 1989.

immediately after the beacon-only test program is formalized since this will provide valuable controller inputs with respect to the acceptance of the beacon-only system and NEXRAD weather surveillance products. Early changeover of an LRR to a beacon-only site will demonstrate feasibility and provide valuable lessons for future site conversions.

Defining installation and checkout (INCO) procedures and performing operational readiness demonstrations must be scheduled and implemented on a site-by-site basis because of the differences in equipment complements at each site. Thus, a site-specific INCO plan must be developed for each site.

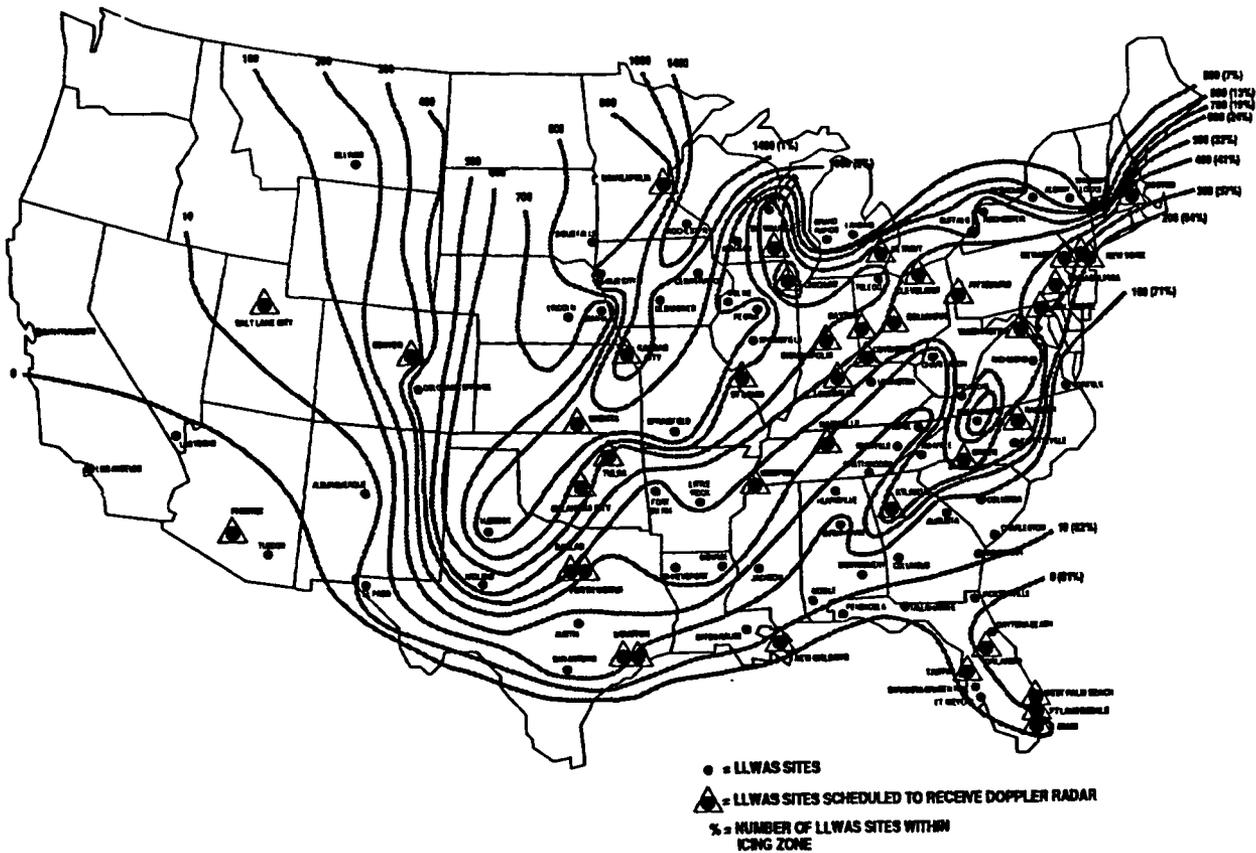


Figure 3-2. Icing Contour Map based on 24-year Icing Statistics - Icing Intensity in CONUS in terms of Total Hours per 24-year Period

3.1.2 Ground Equipment Transition

This section addresses hardware/software considerations. Specifically, the following elements are discussed:

- Existing Beacon Antennas:
- Radome;
- Pedestal;
- Rotary Joint;
- Maintenance
- Site Conversion; and
- New Antenna Structures.

3.1.2.1 Existing Beacon Antennas

Existing en route sites employ NADIF (NAFEC DIpole Fix) secondary surveillance antennas, with radiating elements that are adjacent to the primary radar antenna feed horn and make use of its reflector. At en route facilities receiving the Mode S system, the secondary antenna will be mounted on top of the primary reflector and, at sites where the ARSR-4 will be installed, the secondary antenna will be chin-mounted. The physical restrictions for an en route antenna are as follows: the overall dimensions of an array will not exceed 70 inches high by 27 feet long by 35 inches deep including all mounting brackets that are an integral part of the array structure. The antenna weight of 700 pounds, excluding rotary joint, allows rotation rate up to 17 rpm⁷ (1 rev. per 4 sec.).

The Mode S en route beacon antenna is electrically similar to and approximately the same size as the terminal antenna, differing primarily in its vertical illumination pattern and mechanical construction. To provide maximum detectability at long range, it employs a cosecant-squared vertical pattern rather than a fan beam. Thus, the power distribution network in its individual vertical columns has components of different values from those in the terminal antenna. Under current plans, two such antennas mounted back-to-back are to be employed at en route sites as shown in Figure 3-3.

The Mode S installations at beacon-only sites do not require a Common Digitizer. The CD provides a digitized primary radar report for merging with the beacon report in the Mode S system. This is not available at beacon-only sites. The CD is also available for Interim Beacon Interrogator (IBI) backup if both data processing systems in the Mode S should fail. If there is no primary radar, failure of the DPS backup is not sufficient justification for the CD. This is the configuration at the existing en route beacon-only sites⁸ with Mode S beacons.

Since the primary antenna requires weather protection, a radome is necessary. The new Mode S antenna incorporates a back plane structure that also requires weather protection.

⁷DOT/FAA Product Specification for Mode S Antenna Group, En Route Array, FAA-E-2751, May 26, 1987.

⁸Tonopah, NV; and Rock, NE.

This design reduces coupling and interference in back-to-back antenna installations. In the absence of the primary radar, the scan rate of the beacon antenna can be increased to provide a 5-second scan rate, thereby precluding the need for back-to-back (dual) Mode S/ATCRBS antennas. A single antenna can be used. Modifications to the terminal antenna design, changing its vertical illumination to that of the en route antenna (i.e., producing csc^2 vertical pattern) would allow its use in en route, thus eliminating the need for a radome at most locations except where subjected to severe winds and icing.

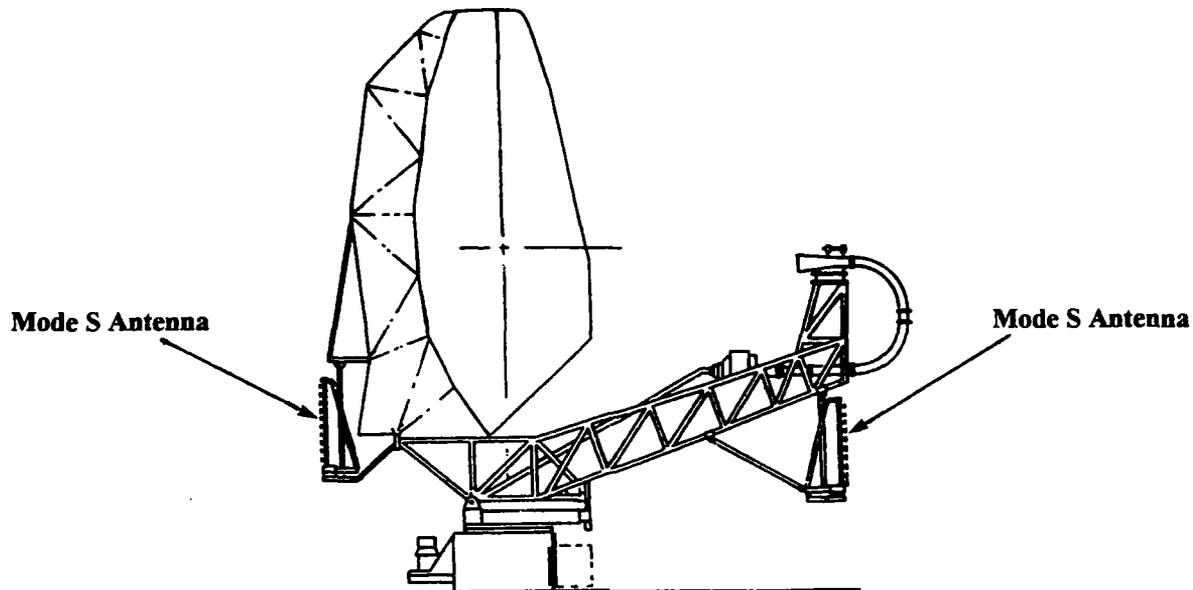


Figure 3-3. Mode S Antennas Chin-Mounted and Back-Mounted on ARSR-3 Radar

This design is consistent with the reduced fruit environment that will result from monopulse operation, and with Mode S data transmission requirements. The ability of existing en route radar processing software to operate with the higher scan rates must be evaluated. Communications data rate requirements will also grow due to the increased scan rate.

3.1.2.2 Radome

The current radome, Figure 3-4, employs geodesic dome construction (metallic lattice work) which degrades beacon monopulse performance. A new radome is presently being designed for those dual sites that are to be upgraded to Mode S. If primary radar were removed from en route sites and modified terminal antennas used, considerable savings could result from removal of the radome. This depends on whether terminal antennas can be modified for the en route application and the severity of weather at the en route sites. As noted above, modification would consist primarily of changes to the vertical feed networks to produce a cosecant-squared pattern rather than a fan-beam. This appears attainable through use of components (splitters, attenuators) of different value.

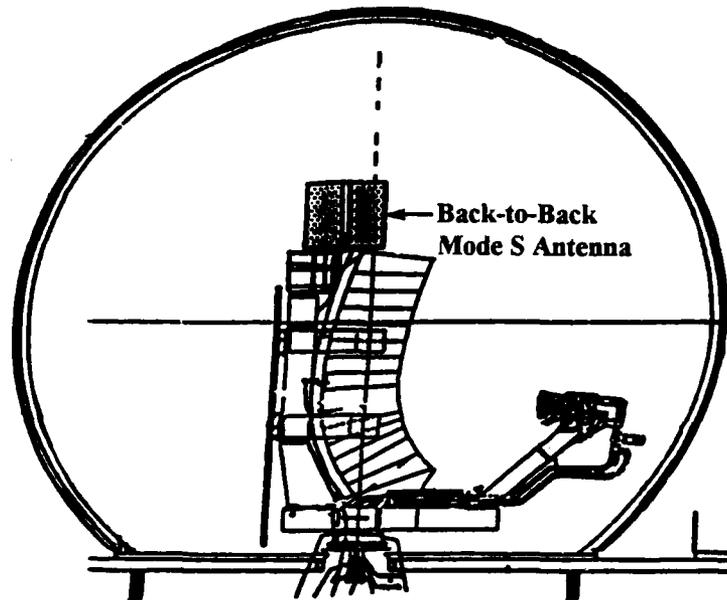


Figure 3-4. Typical Radome Antenna Protection

3.1.2.3 Pedestal

The large pedestal now in use, which supports the massive primary antenna, requires frequent and sometimes extensive maintenance. For example, as part of scheduled maintenance, 15 to 18 pedestals are overhauled each year. Another 8 to 10 emergency repairs are performed annually. A smaller pedestal, sized to the lighter beacon antenna, would be less expensive to construct, operate, and maintain, and could readily accommodate the higher scan rate.

3.1.2.4 Rotary Joint

The rotary joint configuration for en route operation of Mode S with primary radar is shown in Figure 3-5.

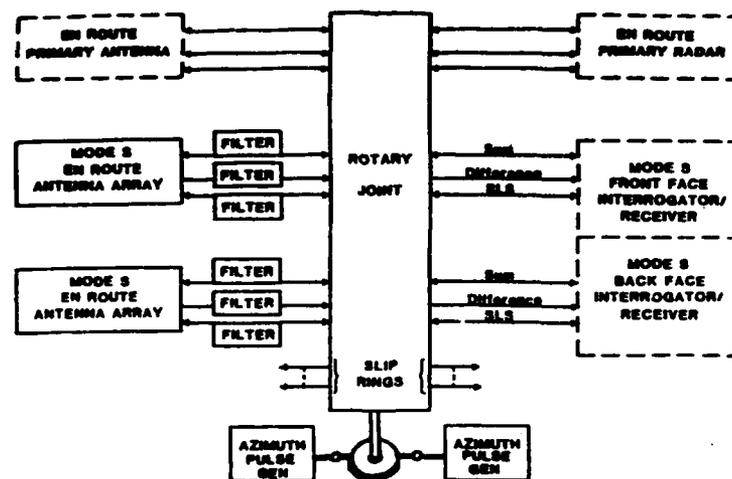


Figure 3-5. Mode S En Route Array Group Functional Diagram: Rotary Joint

It consists of two three-channel sections (one for each beacon antenna) and a single primary radar section. Only one three-channel section would be required for single beacon antenna monopulse operation. It would seem prudent therefore to install three-channel rotary joints at all ATCBI-4 and ATCBI-5 sites since the ATCBI-3 sites will be replaced by Mode S. In the case of the ARSR-4 radar, a six-channel secondary and multichannel primary rotary joint would be used to support back-to-back Mode S antennas to achieve a 6-second target update rate with a 12-second antenna rotation rate.

3.1.2.5 Maintenance

The current LRRs have limited remote maintenance monitoring (RMM) capabilities via the Remote Control Interface Unit (RCIU). When LRR/beacon sites are converted to beacon-only sites, then an enhanced RMM system will be needed. This will be similar to the RMM at beacon-only sites and at the ARSR-4/ATCBI sites.

A programmatic consideration that must be investigated is whether implementation of these maintenance modifications to the ARSR-1, -2, and FPS, as part of the transition to a beacon-only radar system, will adversely impact the transition to the Mode S radars.

Maintenance of the en route radars will be performed from the ARTCC with the System Maintenance Monitor Console (SMMC - developed in the 1970s) and its associated Maintenance Processor System (MPS). To implement the Remote Maintenance Monitoring System (RMMS - evolved in the 1980s) into the existing ARSR-1, -2 and FPS-20 radars required an upgrade of some of the radar subsystems, namely the RCIU to respond as an RMS and the CD to interface with radar equipment. For the ARSR-3, these maintenance concepts were included in the design. At the SMMC location, the MPS computer software required a redesign to perform new maintenance functions. This software is called Interim Monitor and Control Software (IMCS) since it precedes the final MCS software.

For the next generation maintenance, the FAA is planning to establish Maintenance Control Centers (MCC) that will provide centralized monitor and control capabilities for ARTCC equipment and the NAS equipment assigned to sector locations. The facilities are to be called ARTCC/MCC or AMCC and at the sector level, General NAS/MCC or GMCC.

This system will have a single Maintenance Processing System (MPS) located at ARTCC/ACF to service both the AMCC and GMCC. For RMMS purposes, the Interim Maintenance Control Software (IMCS) will continue to provide the maintenance functions for the ARSR-1, -2, and the FPS-20 radar systems until the Maintenance Control Software (MCS) is operational. The discrete data associated with these radars will be acquired for the Data Acquisition Subsystem (DAS) by the MPS and displayed by the Real-Time Status Display (RSD), Figure 3-6.

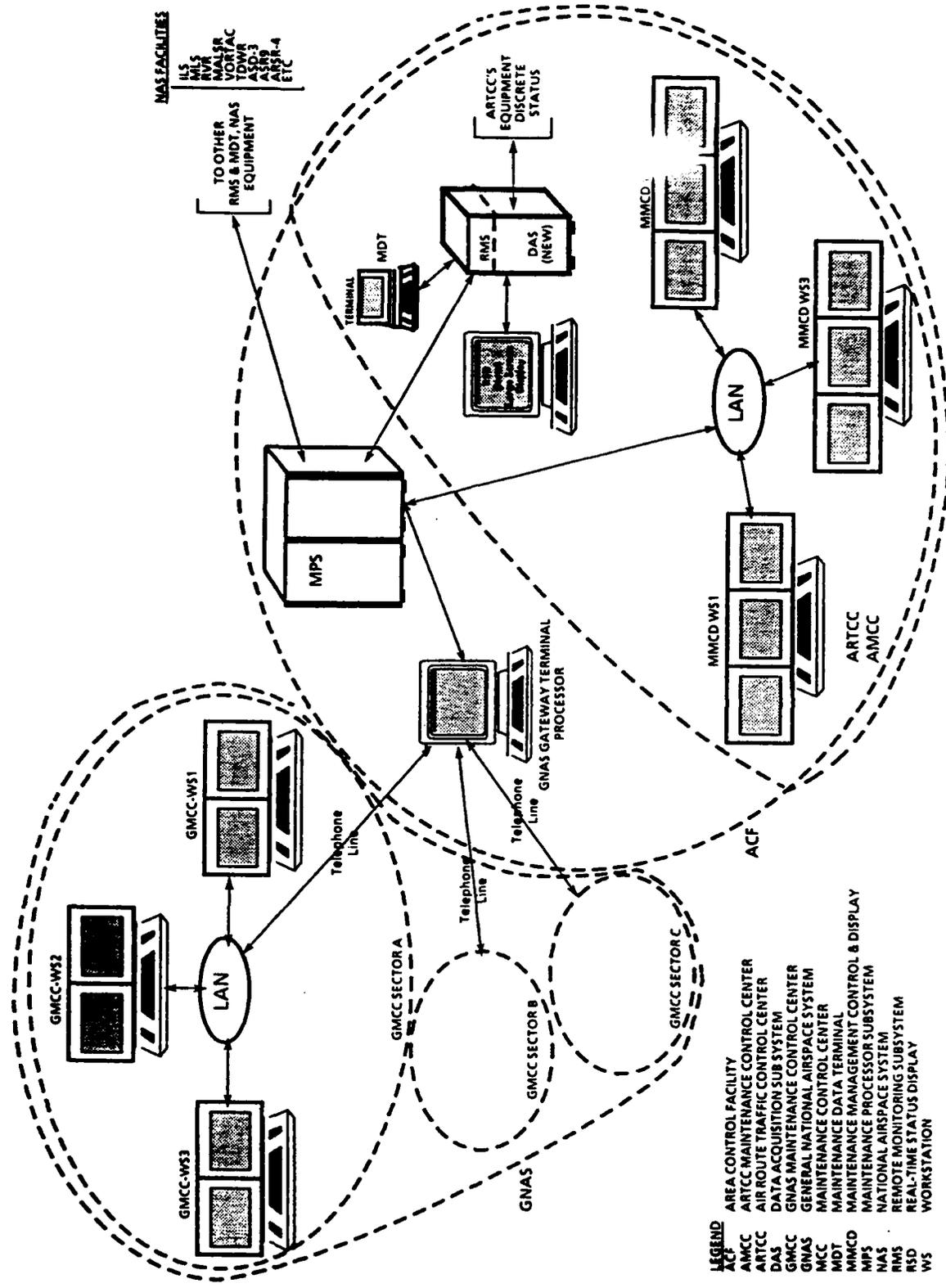


Figure 3-6. AMCC/GMCC Maintenance Center

A program to install RMM at beacon-only sites is underway. This modification uses Remote Monitoring Subsystem (RMS) whose function is to interface with the ATCBI-5, the Integral System Monitor (ISM), and also with the Initial Remote Monitoring Modification (IRMM) in the CD-2 and to perform some basic functions including channel changes and resetting of the CD-2 by momentarily removing 3-phase power at the input.

For the JSS sites, the Air Force requested remote control of the CD-2 search sensitivity by monitoring the Leading Edge (LE) and Distribution Free (DF) curves which are parts of the Search Target Processor on the CD-2, before the FAA can reduce watch coverage at the sites. Modifications to the CD-2, the ARTCC software, and to the RCIU are being developed to enable remote control of these changes to CD-2 operational parameters. Since remote control of the CD-2's search sensitivity is required, an enhancement to IRMM is needed. This modification was developed in Alaska, but it needs NAS Change Proposal (NCP) for national adoption and additional software. Another factor to be considered is that the Mode S implementation, when installed, will replace CD-2 and its associated IRMM subsystem.

The maintenance impact caused by shutdown of the ARSR-1, -2, and FPS-20 series primary radars is as follows:

- The Remote Control Interface Unit (RCIU) RMS software for the primary radar will be deleted. Any dependency of the secondary radar on primary radar data will be removed;
- CD-2 interfaces with primary radar will be removed;
- Maintenance Data Terminal (MDT) software to service the primary radar will be deleted and will only accommodate secondary radar;
- RMS timing for primary-to-secondary radars will be redefined (e.g., startup, restart) since timing is presently initiated from the primary radar;
- The software interface for ARSR and FPS radar performance tests will be modified for beacon-only operation; and,
- Surveillance Data Recorder (SDR) files will be purged to exclude primary radars.

At present, the IMCS software is operating with the ARSR-3 and the ARSR-1, -2, and FPS-20 radars that use the CD-2. The MCS software for the planned RMMS is currently being written. The new replacement radars, namely Mode S and ARSR-4, will not be supported by the IMCS until the IMCS DECODER processor for each radar is available. The IMCS DECODER receives raw digitized data from the radar's sensors and reformats data into a common format for storage in the IMCS data file. In order to support the system, IMCS will continue to be required for the new MPS until the MCS software is operational.

3.1.2.6 Site Conversion

The entire long-range radar antenna structure is enclosed in a hemispherical radome (see Figure 3-7). Search and beacon radar electronics are housed in a shelter within or beneath the antenna tower. The beacon electronics require one equipment rack; the remainder of the equipment (several racks) are devoted to the search radar, digitizer, and other common equipment. Based on engineering judgment and discussions with FAA personnel, conversion of a dual-radar installation to a beacon-only site is expected to involve the following mechanical and structural changes:

- Removal of primary radar electronics from the equipment room;
- Removal of the radome; and,
- Replacement of the common pedestal, primary antenna and secondary radar antenna by a new secondary antenna capable of operation without a radome.

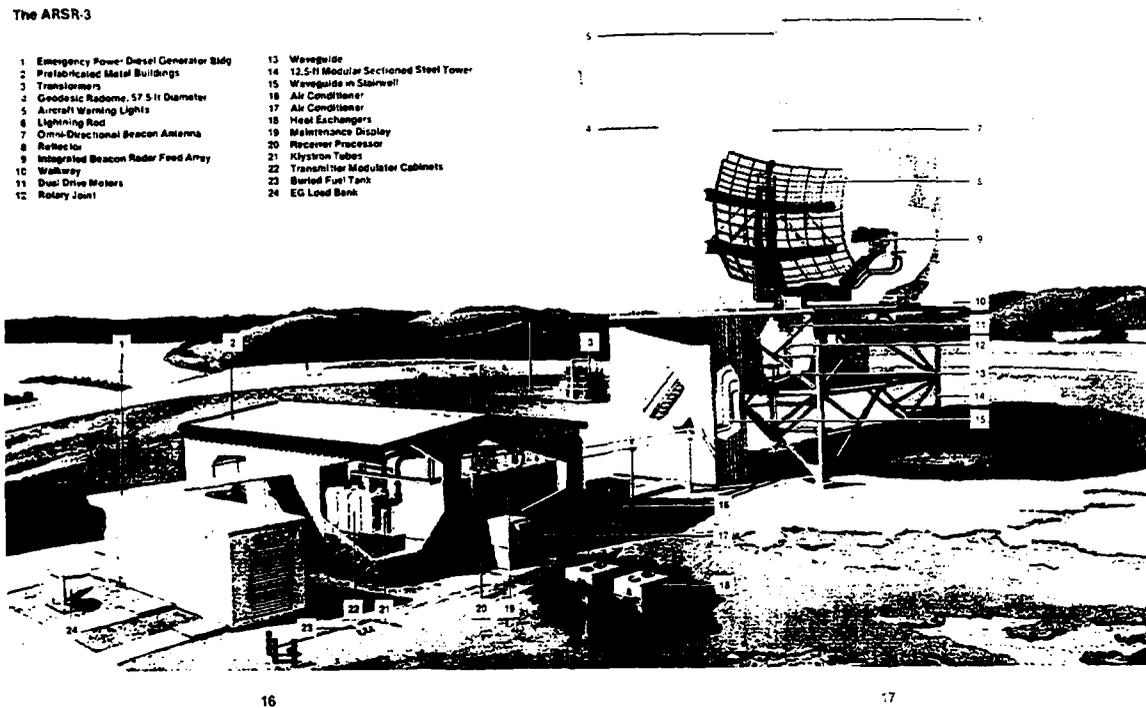


Figure 3-7. ARSR-3 Standard Configuration

Electrically, the primary and secondary radars are largely independent. A block diagram of a typical tube-type system is shown in Figure 3-8.

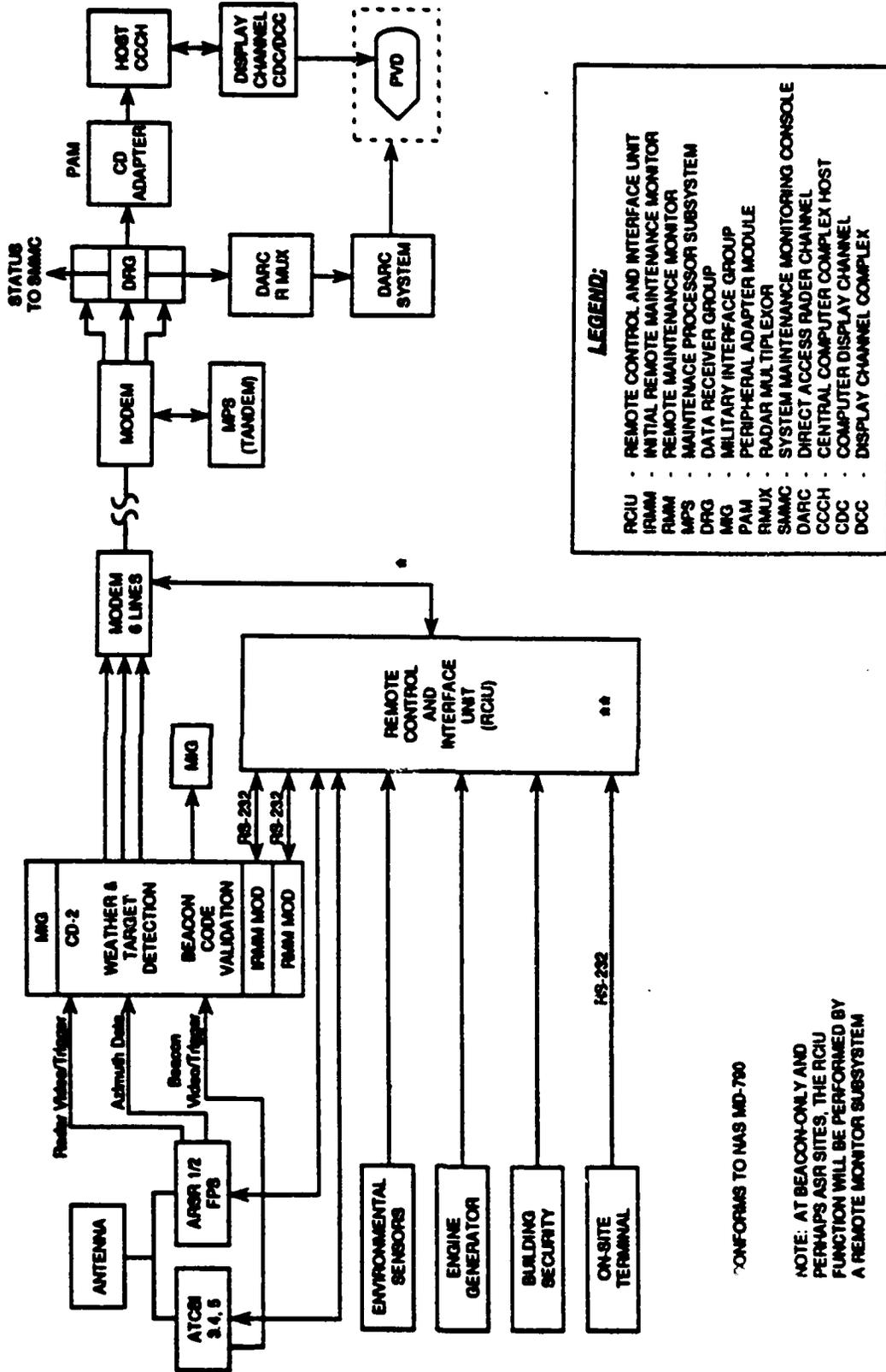


Figure 3-8. Block Diagram of FPS-20, ARSR-1 and ARSR-2 Site

Secondary radars are sometimes deployed separately at so-called "beacon-only" sites, as shown in Figure 3-9. Reliability requirements demand that the primary and beacon radars at dual sites be electrically independent so that failure of one radar will not cause failure of the other. There are, however, three interfaces between the two radars that must be considered in converting a site to beacon-only operation (see Figures 3-8 and 3-9).

These interfaces are:

- Beacon Trigger - In dual sites, beacon transmissions are triggered from the primary radar. However, the beacon can be made to self-trigger by providing an appropriate timing source;
- Common Digitizer - The CD-2 will operate properly without primary radar returns; however, azimuth inputs from the antenna structure must be retained; and,
- Beacon Performance Monitor - Can be retained without modification.

Radar interfaces with ARTCC, ACF/ACCC, and RMMS must also be modified to remove primary target processing, formatting, and target tracking hardware and software. There are, however, no significant electrical issues associated with converting a dual radar installation to a beacon-only site that has been identified in this study.

The following antenna and ancillary equipment characteristics may be realized with a new rotating en route beacon antenna as shown in Figure 3-10:

- Use of new radomes at severe weather locations;
- A new single en route open array monopulse antenna design;
- New installation and equipment (tower, rotary joint, APG, trigger unit);
- Rotation rate of approximately 12 rpm (17 rpm new antenna design limit);
- Range: 100 nm;
- Capacity: 400 aircraft.

The ASTA program is examining the use of ADS/GPS based on a modified TCAS squitter capability to transmit aircraft position from the aircraft to the ground system on the Mode S data link. To implement this mode of operation and to provide 6000-foot altitude coverage, a new six-segment phased array antenna design has been proposed by Lincoln Laboratories. A concept of this antenna is also shown in Figure 3-10.

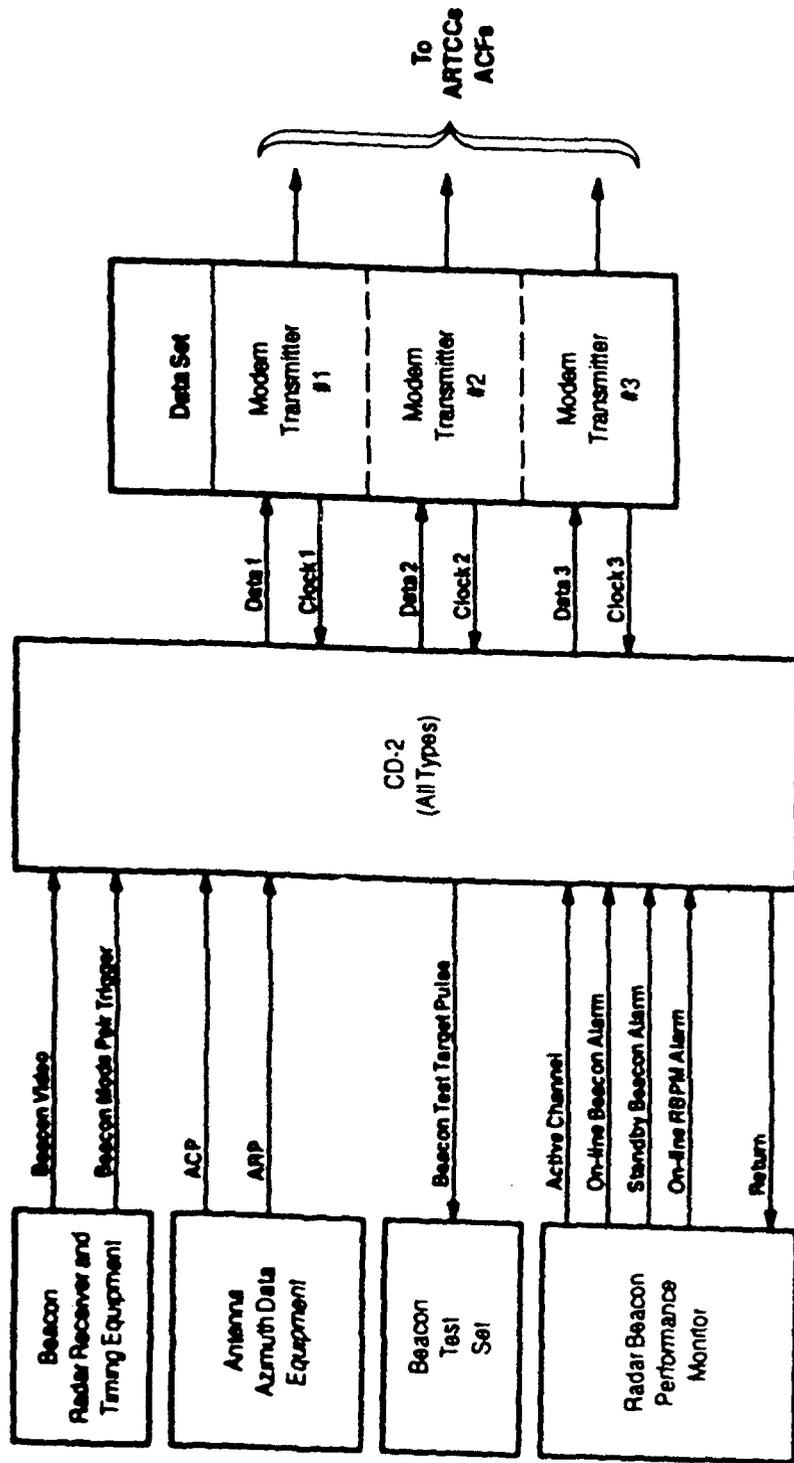
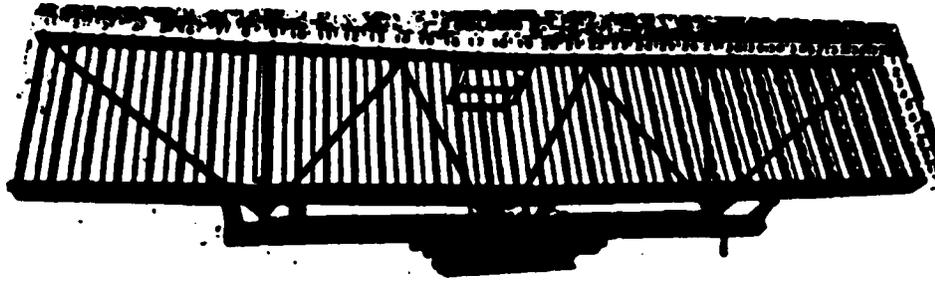
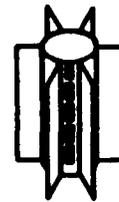


Figure 3-9. Data Flow at Beacon-Only Site (Non-Mode S)



Open Array Beacon Antenna



6-sector Phased Array Antenna

Figure 3-10. Open Array Beacon Antenna and 6-sector Phased Array Antenna

This antenna provides 360-degree receive-only coverage up to 100 nm using six very sensitive receiver channels. The range reduction will provide 6 dB or better improvement in signal strength but compensation for the loss in antenna gain with the wider horizontal beamwidth is a challenge. Features of the new six-sector antenna are as follows:

- No radome: use radomes only at difficult environmental sites;
- Phased array 5 feet high with six-sector antenna;
- No rotating parts, rotary joints, drive motors, APGs, etc.;
- 60-degree beamwidth;
- 100 nm coverage;
- 6-channel receiver with sensitivity below -105 dBm/MHz;
- New tower;
- 400 aircraft capacity;
- ADS compatibility.

Coverage analysis for site locations to satisfy the 6000-foot and above requirement is necessary as well as ARTCC, ACF/ACCC, and RMMS interface analyses. While this antenna has potential application in the distant future for ADS and data link it may not provide an antenna replacement for the en route beacon radar system.

3.1.3 Airborne Equipment

Avionics, especially the ATCRBS transponders, is not affected by the transition to beacon-only operations. The new Mode S radar can detect both ATCRBS transponder and the new Mode S transponder and is fully compatible with ATCRBS operation. The status of Mode S is such that the full design, including the 24 standard message formats, has been tested in the field and is being produced. TCAS squitter⁹ is an incremental part of the Mode S design. A modification to the squitter mode of the Mode S transponder will add the capability of transmitting ADS/GPS-aircraft-derived position information to the ground system. Lincoln Laboratory has adapted a Mode S transponder to receive GPS-derived position data and transmit aircraft position to the ground using the Mode S squitter mode. This capability was successfully demonstrated in a flight test conducted at Lincoln Laboratory during the summer of 1993. Analysis and further testing must be conducted to determine the degree of interference caused to ATCRBS and Mode S operations by the squitter messages.

The most significant effect of the deactivation decision on aircraft will be the need for rulemaking that will require that all aircraft flying above 6000 feet carry a transponder with altitude reporting capability (assumed to be ATCRBS or Mode S) and that all IFR flights be transponder-equipped regardless of altitude. The Decision Memorandum specifies that this rule will be effective after 1997.

3.1.4 Site-by-Site Implementation Scenario

There are two implementation scenario elements that must be addressed. The first consists of a global deactivation strategy that determines the center transition schedule and the order of LRR site decommissioning, while the second develops site-specific deactivation schedules.

One of the most critical issues associated with the transition strategy is sustaining the existing system until deactivation can be accomplished. Resources are required to sustain the present LRRs so that an orderly transition can be accomplished. The alternative of allowing the existing primary radar system to fail in a haphazard fashion is unacceptable. Thus, because of the age of many of the existing radars and because of the scarcity of funds, the earliest possible transition is desired.

The global transition strategy and schedule is based on the following constraints:

- Transition to the beacon-only system must be accomplished at a center level. In other words, NEXRAD weather information must be available and provide center airspace coverage, the WARP must be in place, and beacon coverage of center airspace above 6000 feet must be operational. Once these conditions are met, the primary radar signals into the ARTCC can be disabled, and site-by-site deactivation of the primary

⁹Traffic Alert and Collision Avoidance System randomly transmits, omnidirectionally, an aircraft identity code once per second.

LRRs within the center can be accomplished provided that there are no other ARTCCs supported by the same radars.

- Failed weather radars can cause significant ATC problems, up to 15-minute or 1-hour recovery time, procedures for obtaining supplementary information from the NWS should be examined.
- Deactivation of the primary LRR radars within an ARTCC should proceed in a fashion that provides the most critical radar parts necessary to sustain the remaining operational LRRs. Cannibalization of deactivated radars to sustain those radars at ARTCCs that are later on the transition schedule will be required in order to minimize the resources required to sustain the LRRs.

Thus, a global schedule that identifies the transition date for each ARTCC must be developed based on the "health" of the radars within each ARTCC. Health would be assessed on the basis of age and maintenance history. For example, an ARTCC that contains "healthy" radars would have a later transition date than one with radars about to fail. Note that the schedule must be flexible to accommodate unanticipated LRR failures.

Using this strategy for transition to the beacon system has the following advantages:

- A single but complete center is commissioned for beacon-only operation and the use of NEXRAD weather data; and
- Deactivated LRR sites within a beacon-only ARTCC can be used to sustain other LRR radars that are scheduled for decommissioning at a later time.

3.1.5 Operational Procedures Development

Before transition to beacon-only operation can take place within an ARTCC, certain operational procedures must be developed and tested. These operational procedures must address the normal, fail-soft, and fail-safe modes of operation. The procedures must include, at a minimum, the following:

- Delete primary radar requirements;
- Failed NEXRAD radar; and,
- Spill-ins/-outs from Military Special Use Airspace (SUA).

In the event of a failed beacon radar, procedures for switching over to another beacon radar that may be covering the same airspace must be examined. In the event that dual coverage does not exist, reverting to non-radar procedures or pilot reporting needs to be examined. Also, rerouting traffic around the airspace that is not covered by beacon may be necessary. If ADS is available and most aircraft are equipped, it may be possible to switch over to an ADS form of surveillance until the beacon radar is repaired (i.e., use the

ADS as a backup to the beacon-only surveillance system). Additional beacon-only sites would also provide redundant coverage.

Military operations in Special-Use Airspace (SUA) often involve high-speed, high-performance aircraft that are deliberately flying without operating transponders. Studies have shown that two potentially dangerous situations occur during these operations: Spill-ins¹⁰ which involve a civilian aircraft blundering into the restricted special use airspace and spill-outs which involve the military aircraft accidentally exiting the designated SUA.

Spills-ins will continue to be a problem and are not always due to a blunder by the pilot. On occasion, aircraft operators are obligated to deviate for weather or traffic, this deviation may require penetrating a military special use airspace. Once this occurs, traffic advisories will not be available when the primary radar is deactivated.

The only protection against these situations has, in the past, been primary radar. To protect against this event, procedures for selection of SUA should consider the availability of ASR primary radar coverage for the designated SUA. Spill-outs can also be handled by providing a buffer zone around SUA that is covered by ASR radars. In any event, procedures must be established to provide some type of protection once the LRRs are deactivated.

3.1.6 Summary of the Transition Strategy

The recommended strategy for transition from the present primary/secondary surveillance system to a beacon-only surveillance system consists of the following features:

- Deactivated LRRs within a beacon-only commissioned center will be used to sustain LRRs in centers awaiting transition to beacon-only operations.
- The transition to the beacon-only en route radar surveillance systems will be dependent upon the NEXRAD deployment being completed;
- Transition to beacon-only operation will be accomplished on a center (ARTCC)-by-center basis. The transition schedule for centers will consider the overall health of the LRRs within each center and the availability of NEXRAD coverage;
- The schedule for deactivation of radars within a commissioned center, when the center is ready and waiting, will be based on the need for critical primary radar components in other centers;

¹⁰Joel M. Yesley, FAA: Richard W. Kitterman, Martin Marietta: Influence of Primary Surveillance Radar on Incidence of Mid-Air-Collisions Due to Spill-outs/Spill-ins around Military Special Use Airspace, November 1991.

- Beacon coverage to 6000 feet will be accomplished by integrating both the terminal beacon and the en route beacon system with 100 nm coverage range capability and by providing additional beacon radars;
- Rulemaking concerning the carriage of transponders by all aircraft above 6000 feet and by all IFR flights must be implemented on a schedule that will ensure transponder equipage at the time of ground system transition;
- Procedures for normal, fail-soft, and fail-safe operation must be developed, tested, and implemented prior to actual commissioning of a center for beacon-only operations;
- The goal of establishing stand-alone beacon sites is part of the strategy and includes the eventual implementation of new antennas, pedestals, and other needed structural, mechanical and electrical components that prove to be cost-effective;
- Site conversion will be evolutionary and will eventually remove all primary radar components although this will not be necessary before center transition;
- A JSS system composed of ARSR-3, ARSR-4, and AN/FPS-117 radars will be implemented.

3.2 IMPLEMENTATION PLAN

The formulation of the LRR deactivation decision implementation plan is closely coupled with the recommended transition strategy. The Decision Memorandum has identified a future system state in which there is no en route primary radar system and in which NEXRAD provides the required weather information to the en route controller. The recommended transition strategy provides a road map of how to evolve from the existing system to the specified future beacon-only surveillance system.

The implementation plan identifies the schedules and resources required to implement the recommended transition strategy. This implementation plan is based on a work breakdown structure (WBS) which serves as the basis for the schedule and resource planning estimates presented in the following sections.

3.2.1 Work Breakdown Structure

The development of the work breakdown structure involves defining tasks and organizing the work necessary to deactivate the en route primary radars. This WBS has been developed to achieve effective, efficient, and timely transition to an all-beacon system subject to the budget and budget process constraints.

Figure 3-11 presents the LRR deactivation WBS to the third level. This summary WBS is sufficient to derive preliminary schedule and resource estimates.

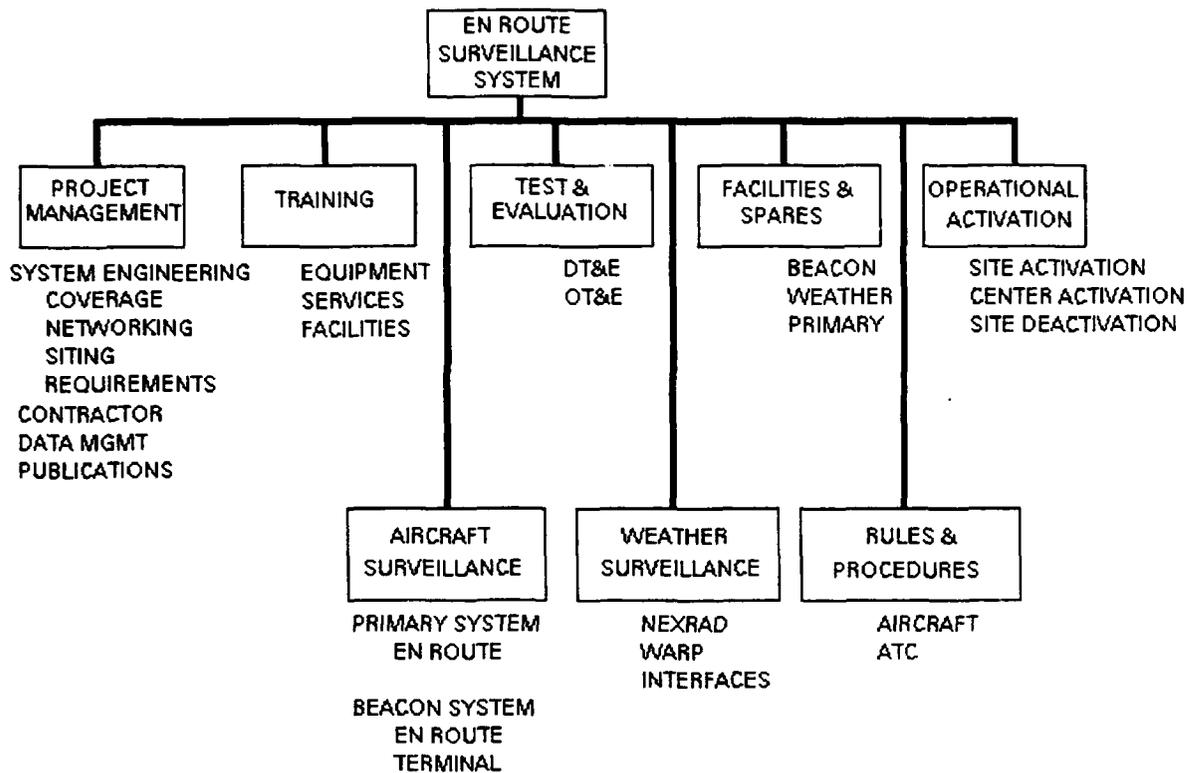


Figure 3-11. Work Breakdown Structure

3.2.2 Implementation Programs and Schedules

The development of the implementation schedule is contingent on the schedules of several programs which lie in the critical path of deactivating the LRRs. These programs include: NEXRAD; WARP; ISSS; Wx INTERFACE (ISSS/WARP); ACCC; RMMS; Mode S (first and second buys); New ATCRBS Sites as an alternative to the Mode S second buy; Transponder Rulemaking; and, ARSR-4 as shown in Table 3-1.

Table 3-1. Critical Program Schedules

Program/Year	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10
NEXRAD (24-16)																	
WARP (43-02)																	
ISSS (21-12)																	
Wx Interface (63-02)																	
ACCC (21-12)																	
RMMS (26-01)																	
Mode S																	
Mode S (2nd buy)																	
ATCRBS																	
NPRM Xpndr Rule																	
ARSR-4 (24-15)																	

These programs are necessary to satisfy the requirements of the NAS-SR-1000, DD-1000, SS-1000, and the Decision Memorandum. Examination of the program schedules indicates that the pacing item is the Mode S second buy or the expansion of the ATCRBS system to provide coverage above 6000 feet. Based on the other programs, the earliest possible transition to a beacon-only en route capability appears to be the year 2000 with the most likely transition occurring about 2003 after the ACCC and RMMS projects are completed. If the ISSS/WARP interface issue can be resolved and additional beacons procured, the year 2000 becomes a very feasible transition date. Early transition will mitigate the sustain and support problems associated with the aging LRRs. However, the transition could be initiated as late as 2008 which would require maintaining the LRRs for an additional 15 years.

In conclusion, the actual transition date will be determined by three principal issues:

- The ability to achieve en route beacon coverage to 6000 feet;
- The ability to implement ISSS;
- The ability to provide the NEXRAD reflectivity weather products to the common console.

It is recommended that the beacon system coverage issue be critically examined to determine the minimum number of additional new beacon systems necessary to achieve 6000-foot coverage. This study would also examine increasing the terminal beacon system range to 100 nm and maintaining the existing ATCBI en route capabilities with possible relocations and new gap fillers. It is further recommended that the interface issue between the WARP and the ISSS be resolved so that transition can be initiated by the year 2000. This assumes on-schedule ISSS implementation. Based on recent overruns and potential slips, every effort should be made to solve the problems associated with display of NEXRAD reflectivity products on the existing PVD.

Given the uncertainty associated with the actual date that transition will be initiated (i.e., 2000 to 2008) it is important to examine the programs necessary to sustain/support the

LRRs over the longest time span. Thus, three sustain/support scenarios will be examined, the first, which requires that the LRRs be sustained until the year 2002, (i.e., the *optimistic scenario* that initiates transition in the year 2000); the second, which requires that the radars be sustained until the year 2005, (i.e., the *most likely scenario* that initiates transition in the year 2003); and the third, which requires that the LRRs be sustained and supported until 2010 (i.e., the *pessimistic scenario* that initiates transition in 2008).

A 2-year transition period has been estimated based on the assumption that 5 months of transition time would be required for each ARTCC (3 months for center transition to beacon-only operation and 2 months for decommissioning of radars). It is also assumed that up to five centers will be in transition at any one time. According to this schedule, one center a month will be commissioned for beacon-only operation. This takes 24 months to commission 20 centers for beacon-only operations and to deactivate the long-range primary radars within each center.

Based on the WBS, implementation of the overall LRR Deactivation Program consists of the following elements with special notations in parenthesis:

LRR Deactivation

Program Management

- System Engineering & Support
 - Requirements (Coverage, JSS)
 - Coverage (Beacon and NEXRAD)
 - Networking
- Data Management (Configuration Management)
- Publications
- Contractor Management

Training

- Equipment (New equipment)
- Services (All beacon operations; NEXRAD Wx products)
- Facilities (New facilities)

Test and Evaluation

- DT&E (Interfaces)
- OT&E (Test Plans)

Operational Activation/Deactivation

- Centers (Commissioning for beacon-only)
- Radars (Activate Beacons, Deactivate Primaries)

Facilities and Spares

- Beacon
- Weather
- Primary (Develop strategy given deactivation)

Rules and Procedures

- Aircraft (NPRM)
- ATC (Failure Modes and Analysis)

Weather Surveillance

24-16 NEXRAD (examine site locations)

43-02 WARP

63-02 CWP (WARP) Interfaces

Aircraft Surveillance

Primary System (sustain)

44-39 Sustain/Relocate ARSR

44-40 LRR Improvements

44-42 LRR Radome Replacements

44-43 Radar Pedestal Vibration Analysis

Disposition of Primary Radar

Beacon System (implementation)

24-12 Mode S (first & second buy)

34-12 ATCBI Establishment (New Beacon Sites)

44-45 ATCRBS Relocation (Based on Coverage requirements)

44-46 ATCBI Replacement (Based on Mode S or New Beacon)

xx-xx Terminal Beacon Enhancements (Extend range of terminal beacon systems)

The following program schedule (Table 3-2) has been developed using the WBS. It has been generated based on a start date of January 1, 1994, with transition at the first center beginning in 2000, 2003, and 2008 respectively. The schedule identifies the initiation and completion of each of the WBS elements and uses the heavily shaded bar for the optimistic scenario, the medium shaded bar for the most likely scenario, and the lightly shaded bar for the pessimistic scenario.

Within this program structure, there are two basic categories of programs necessary to support the deactivation decision:

- LRR Sustain/Support Programs;
- New and Modified Programs.

The programs in the sustain/support category are required to maintain and extend the life of the existing LRRs until they can be decommissioned. In general, the sustain/support program requirements for the LRR are included in the CIP and consist of the following:

44-39 Sustain/Relocate ARSR;

44-40 LRR Improvements;

44-42 LRR Radome Replacements; and,

44-43 Radar Pedestal Vibration Analysis.

Table 3-2. LRR Deactivation Program Schedule

WBS Element/Year	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10
Program Management																	
Training																	
Test and Evaluation																	
Operational Activate/Deactivate																	
Facilities and Spares																	
Rules and Procedures																	
Aircraft/NPRM																	
ATC																	
Weather Surveillance																	
24-16 NEXRAD																	
43-02 WARP																	
63-02 CWP Interface																	
Aircraft Surveillance																	
Sustain Primary Sys.																	
24-15 ARSR-4																	
44-39 Sustain																	
44-40 LRR Impr.																	
44-42 Radomes																	
44-43 Pedestal																	
Disposal of Radars																	
Impl. Beacon Sys.																	
24-12 Mode S.																	
34-12 ATCBI Est																	
44-45 ATCRBS Rel																	
44-46 ATCBI Repl																	
MILESTONES																	
Scenario 1 Operational Transition																	
Scenario 2 Operational Transition																	
Scenario 3 Operational Transition																	

According to the CIP program description for program 44-40, improvements are possible that will permit sustaining the LRRs for up to 15 additional years. This corresponds to the worst-case scenario and, therefore, the sustain/support issue becomes one of cost rather than a technical question of whether the radars can function for the required time. If the transition can be initiated in the year 2000, only 6 years of support is required plus the 2-year transition time. During transition, the deactivated radars can be used to support the active LRRs; thus, the cost may be less than that required for full support.

Disposal of primary radars will be affected to some extent by the cancellation of the leapfrog program. In addition, planning will be required for logistics, storage, and final disposition of hardware. The site cleanup will demand compliance with both environmental and safety rules.

The programs in the second category (i.e., new and modified programs) are required to implement a beacon-only en route surveillance system with modern JSS radars for national security and law enforcement purposes. The primary radars associated with the JSS system will not be used for ATC purposes and the primary radar information will not be available to the en route controllers. The CIP programs in this category that may require modification are:

- 24-12 Mode S (first buy);
- 34-12 ATCBI Establishment;
- 44-45 ATCRBS Relocation; and
- 44-46 ATCBI Replacement (second buy).

All other program elements listed in the above program structure are new and must be defined and their associated costs estimated.

3.2.3 Resource Requirements

The initiation of the transition to a beacon-only en route surveillance system and the associated deactivation of the LRRs cannot begin until at least the year 2000. It will be necessary to support and sustain the LRRs until transition is complete. The required sustain/support period could extend until 2010 according to the pessimistic scenario. This requires that the identified sustain/support programs be fully funded over the time frame of interest. If funding cannot be obtained, it will be necessary to decommission the radars as failures occur and to use the failed radars to maintain the remaining LRRs. This will result in a chaotic transition and could compromise safety and increase system delays due to loss of essential weather information.

In addition to supporting the existing radars, it is necessary to provide the facilities and equipment for changeover to a beacon-only surveillance system. This transition requires additional beacon radar hardware such as rotary joints, beacon trigger generators, antennas and pedestals.

CIP funding projections and allocations, programs in progress, funds needed to complete modernization, and new funds to implement the deactivation decision are identified below. First, consider the existing funding levels. These are provided in Table 2-2 and total \$4.3 billion not including the AWPG and the AAS programs. This funding requires a careful review to ensure compliance with the deactivation decision. The costs associated with the programs required to modernize and extend the life of the existing LRRs for approximately 15 years include:

44-39 Sustain/Relocate ARSR	5.0
44-40 LRR Improvements	30.1
44-42 LRR Radome Replacements	50.4
44-43 Radar Pedestal Vibration Analysis	5.0
Total Modernize/Extend Life Costs	\$90.5M

Based on the Martin Marietta report concerning the deactivation of LRRs, the average cost to operate and support the older FAA radars is estimated at \$789,000/site/year compared to the average costs of \$719,000/site/year for the ARSR-4s. Details of these cost estimates are provided as Appendix F. All costs discussed in this section are in constant 1994 dollars.

Tables 3-3 and 3-4 present the selected elements of the modernization programs currently in progress and those considered to be the absolute minimum required to sustain operations. These program elements account for \$19.48M of the total \$90.5M needed.

Table 3-3. Modernization Programs Being Programmed

1.	Pedestal Vibr.	Pedestal test development (113)	0.65
2.	Cable Cleanup	Cable tray cleanup (113)	1.5
3.	Grounding	Grounding Problem Resolution (113)	0.8
TOTAL			2.95

Table 3-4. Programs Needed to Continue Modernization

1.	Grounding - Interior and exterior (15 upgrades assumed)	3.0
2.	Power conditioning UPS: Electrical power conditioner (55 x \$150K/unit)	8.25
3.	Refurbishment of ARSR-1/2 Transmitters a. Transmitter Cabinet Rewiring and Component Replacements (\$30,000/radar for 41 ARSR-1/-2s) b. Replacement of Antenna Control Unit (\$75,000/radar for 23 radars) c. Replacement of RF Plumbing Components (\$25,000/radar for 20 radars) d. Replacement of Voltage Regulator Units at ARSR-1/-2 facilities	1.23 0.1725 0.50 0.80
4.	Replacement of Existing Rotary Joints with Mode S Units and Replacement of Azimuth Pulse Generators (\$50,000/radar for 40 radars)	2.0
5.	Configuration and Publications Updates	0.17
6.	Improve Reliability of Air Compressor, Dehumidifier, and Transmitter Cooler (\$20,000/radar for 20 radars)	0.40
	TOTAL	\$16.53M

A summary of all surveillance system costs associated with the implementation of the LRR decision is presented as Table 3-5.

The present surveillance system architecture totals 116 radars, consisting of 69 FAA and 47 JSS sites (Table 2-1, Appendix H, Part 1). By the year 2000, projected system architecture will total 143 operational radars, consisting of 78 FAA and 65 JSS (Table 2-2, Appendix H, Part 2).

The estimate to operate and maintain the FAA radars for 1 year is $78 \times \$789,000 = \$61.5M$ and for 8 years until 2002 when the beacon-only system could be operational is \$492.0M. For a hypothetical case, \$21.6M would be saved in the following 4 years if all FAA LRRs were upgraded by the end of 4 years (1998) by replacement with ARSR-4s or similar radars.

The estimate to operate and maintain the JSS radars is derived in a similar manner. The JSS system requires support of 65 sites (see Table 3-6); of these, 43 older radars are located in CONUS. Thirty-one of the older radars in CONUS will be replaced by the ARSR-4 and six will remain as they are. Two ARSR-4s will be located in the Pacific and one site will remain as it is now. All ARSR-4 deployment is scheduled to be completed by the end of 3 years.

Table 3-5. LRR Deactivation Costs

	LRR Deactivation Costs (in 1994 \$M) for Aircraft Surveillance (1994-2002)	LRR Deactivation Direct Costs	Other En Route Surveillance Costs	Total Transition Costs
1.	Modernize/Extend the life of the LRRs		90.5	90.5
2.	Operate/Support 78 FAA LRRs	21.6	470.4	492.0
3.	Operate/Support 41 old and 40 new JSSs		272.4	272.4
4.	Operate/Support 17 Alaska AN/FPS-117		97.8	97.8
5.	Procure 25 Mode S sites (2 Beacon-Only sites)		105.0	105.0
6.	Establish Stand-Alone Beacons (53 Mode S)		222.6	222.6
7.	Disestablish 78 LRRs, site conversion and cleanup	117.0		117.0
8.	Surveillance System Enhancement (CIP 34-40)		180.0	180.0
9.	NEXRAD Implementation		510.0	510.0
10.	Additional Aircraft Transponder Costs ¹¹	Not estimated		
TOTAL		138.6	1,948.7	2,087.3

Table 3-6. JSS Locations

JSS Site/Radar	ARSR-4	FPS-117	Older Radars	Total
CONUS	38	-	6	44
Alaska	-	17	1	18
Pacific	2	-	1	3
TOTAL	40	17	8	65

Then the total JSS inventory will consist of: 40 ARSR-4s, 17 FPS-117s, and 8 other older JSS radars to be kept operational for the full 8-year period (6 in CONUS and 1 each in AK and HI). Another 6 JSS sites outside of the 65-site count, (see Appendix H, Part 2) may or may not be decommissioned as a result of the new ARSR-4 site establishment nearby. The maintenance of all JSS sites yields an estimate of \$272.4M to operate and support the radars until 2002. This total amount (Item 3, 41/40, in Table 3-5) includes the following radars: 40 ARSR-4s for 5 years, 31 older radar replacements in CONUS and 2 in Pacific for 3 years, and 8 older radars for 8 years. In addition, 17 AN/FPS-117 radars

¹¹It is predicted that 80 percent of General Aviation will be transponder-equipped by the year 2000.

Transponder costs are estimated as follows:

Basic ATCRBS transponder for G/A costs	\$ 500
Basic Mode S G/A transponder	\$ 2,500
Basic ADS/Mode S transponder with squitter for G/A aircraft (including GPS receiver, \$1,500)	\$ 4,000
Basic ADS/Mode S transponder with squitter for commercial aircraft, and with redundant unit	\$41,900

are used in Alaska, 16 radars maintained by the military and 1 radar by the FAA. These seventeen radars must be operated and supported for eight years at approximately the same cost as an ARSR-4 site, thus, adding \$97.8M to the total JSS operation and support requirements.

The \$180.0M cost associated with the Surveillance System Enhancements Program (CIP 34-40) must be critically examined. A major portion of this program is focused on the development of the Integrated Radar Beacon Tracker for Modes S and ARSR-4 dual installations.

Next, consider the costs associated with the establishment of en route beacon-only sites and with the disestablishment of the LRRs. The cost of a stand-alone ATCBI-5 site is estimated at \$2.5M without land purchase. The cost of a Mode S stand-alone site is estimated at \$4.2M without land purchase. If land purchases are required, additional costs are estimated at \$0.5M per site. Disestablishment of an LRR, conversion to beacon-only site, and the site cleanup including removal of hazardous materials is estimated on average at approximately \$1.5M per site. Thus, the total cost of establishing a stand-alone beacon-only system can be estimated under the following assumptions:

- Of the 78 FAA LRRs, 25 will receive Mode S in the first buy;
- 53 additional Mode S to replace remaining LRR sites with ATCBI-4/-5;
- 78 primary radars at the LRR sites will be disestablished; and,
- The cost of 25 first buy Mode S en route sites is \$105.0M.

The cost for the 53 beacon-only stand-alone installations is \$132.5M for ATCBI-5s or \$222.6M for the Mode S since the land is presently available for 53 of the sites.

Disestablishment of the 78 primary radars and cleanup of the sites will cost approximately \$117M.

4. ISSUES, RECOMMENDATIONS, AND CONCLUSIONS

This section provides a summary of the results derived from this study. This summary clearly demonstrates the feasibility of deactivating the FAA's LRRs and identifies an implementation strategy that could achieve deactivation by the year 2002. Costs associated with transition to a beacon-only system using NEXRAD weather products are in excess of \$2.0 billion with about \$138.6 million directly attributable to deactivation of the LRRs. Thus, avoiding replacement costs of 1.4 billion appears to be a prudent decision.

Several issues, however, have been identified that require further analysis and decision. These issues, recommendations for their resolution, and overall study recommendations and conclusions are provided in the following subsections.

4.1 LRR Deactivation Decision Issues and Recommendations

The issues associated with deactivation of the FAA's long range radars are identified and discussed. Recommendations for the implementation of the LRR deactivation decision are also presented. These recommendations provide a step-by-step description of how to proceed with LRR deactivation.

4.1.1 LRR Deactivation Issues

The following issues associated with the LRR deactivation decision have been identified and require resolution to accomplish an orderly transition from the present en route surveillance system to a beacon-only system with independent weather radars.

- **NEXRAD/WARP/ISSS Interface:** As stated in the decision memorandum, deactivation of the LRRs is directly dependent on the presentation of NEXRAD weather products to the air traffic controller. Formerly, the FAA plan was to provide the interface of NEXRAD through the RWP to the ACCC. Recently, the RWP and MWP programs have been merged into WARP and there is now a plan to interface the NEXRAD through the WARP to the ISSS. This requires the addition of a "Slice & Dice" computer to the ISSS to partition the center weather mosaic in the WARP for the individual sector suites. This is to be accomplished by the end of 1999 according to current projections. Slips in ISSS and/or WARP will adversely impact the capability of changeover to beacon-only operation. It is recommended that an alternative interface of NEXRAD with the PVD be examined.
- **NEXRAD Coverage:** According to NAS-SS-1000, surveillance and weather coverage is required in en route airspace down to 6000 feet. This requirement is also implied in the Decision Memorandum. Examination of the predicted NEXRAD coverage at 6000 feet shows that the coverage is less than presently provided by the en route radar system. It has also been established from the LRR coverage analysis that the present weather and surveillance coverage at 6000 feet contains coverage gaps and does not satisfy the requirements. (Figure 4.1 shows the present ARSR weather coverage with an overlay of

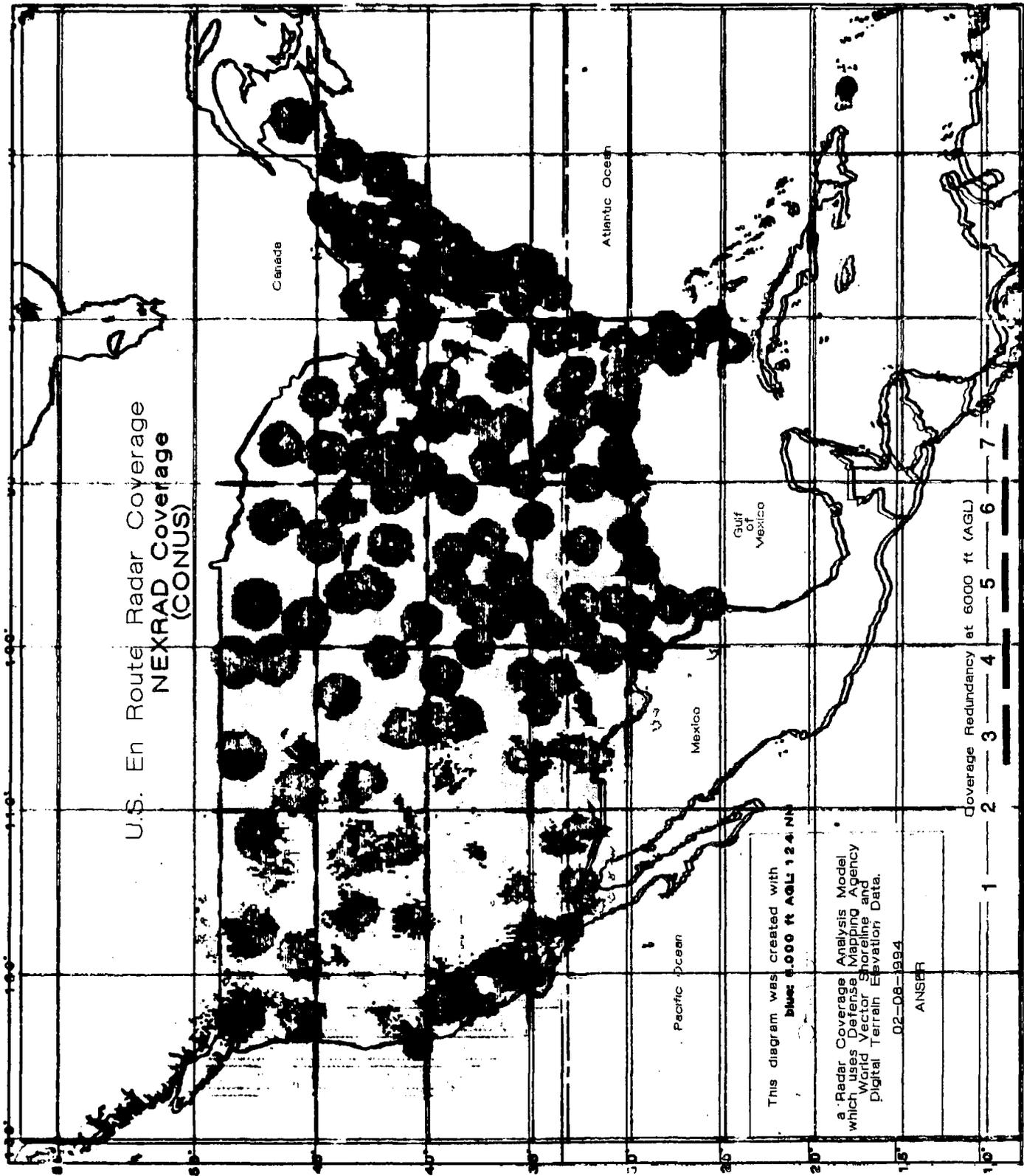


Figure 4-1. ARSR and NEXRAD (at 6000 feet elevation) Weather Coverage

the planned NEXRAD coverage and clearly illustrates the loss of weather surveillance coverage resulting from LRR deactivations.) It is recommended that the NEXRAD scan angle restriction below $+0.5^\circ$ and its siting plan both be reevaluated to determine if alternative sitings will provide improved coverage at 6000 feet.

- **NEXRAD Latency:** The present LRR system provides a complete weather update once every 12 antenna scans for two levels of weather detection. When three-level weather detection is implemented, updates will be accomplished every nine antenna scans. When NEXRAD is compared with LRRs, the NEXRAD will complete its full scan cycle in approximately 5 minutes (average rotation rate = 3.6 rpm, dwelltime = 44 milliseconds per degree, total of 16 scans to cover all elevation angles) and process data within a 6-minute interval, where the LRRs will achieve a complete picture in approximately two minutes (12 scans at 5rpm = 2.4 minutes). The ARSR/NEXRAD comparison study is being conducted but conclusive results are not yet available. The latency issue needs to be addressed as quickly as possible in order to determine if alternatives to the present NEXRAD scanning strategy and/or weather tracking techniques need to be developed to overcome the latency problem. Attention is called to the NAS-SR-1000 requirement for weather avoidance: "Hazardous weather information shall be available to specialists and users within 2 minutes of identification of the hazardous weather phenomenon and shall be maintained current locally to within 2 minutes" (NAS-SR-1000; Paragraph 3.2.6.C.9).
- **ARSR-4 Wx Data Utilization:** According to the most recent statements made by the FAA's System Engineering organization, the ARSR-4 weather data will not be used once NEXRAD data is available. This must assume that there is NEXRAD coverage where the ARSR-4 is located and that the six-minute latency is acceptable to the controller. It is recommended that the WARP acquisition allow for the potential to use the ARSR-4 data should the need arise.
- **NEXRAD Availability:** NAS-SR-1000 paragraph 3.8.1 categorizes NAS services according to Critical, Essential, and Routine. Availability of these services is specified as 0.99999, 0.999, and 0.99 for critical, essential, and routine services respectively. In addition, the goal for a single loss of service to a user/specialist shall not exceed the duration of 6 seconds, 10 minutes, and 1.68 hours for critical, essential, and routine services respectively. Weather Information (strategic); Weather Avoidance, Weather Advisories, and Maintenance Monitoring are all classified as essential services (i.e., 0.99987616 availability; 10 minute max down time). NEXRAD¹ operates in CONUS as a single channel system and, as it is presently being deployed, it will be without full RMMS capability. It is recommended that prior to transition to NEXRAD weather for ATC essential services, a determination be made of how the associated requirements will be satisfied.

¹NAS-SS-1000, Availability Requirement: 0.99987616, Volume 1, January 1990, page 66; and, National Weather Joint Program Office; NEXRAD Availability Requirement C, A(i): 0.999759, R400-SP401A, Table 3-6, page 3-27.

- **FSS Weather Information Impact:** The interface of the NEXRAD/WARP weather information must not only account for the ISSS and the controller but also for the FSS. Presently, weather information is provided to the FSS via the FSDPS. This interface with the FSDPS must be modified or improved for the NEXRAD products to be available to the FSS. It is recommended that this interface be included in WARP procurement.
- **Weather Information in the Cockpit:** In the present system, weather advisories and other information are provided to the pilot via the voice link from the controller and via ATIS broadcasts. The plans for the future system provide that weather information in text and graphical formats will be provided to the pilot via the DLP and the Mode S data link. This capability will be provided by the year 2005. The FAA plans also indicate that the Mode S data link will be the only method for weather products to be delivered to the pilot and that controller voice weather advisories will no longer be used. This could be a particularly difficult issue since it is not required that all aircraft be equipped with Mode S and/or data link capability. It is recommended that this point be clarified as part of the planned NPRM that will address the transponder requirements associated with the LRR deactivation decision.
- **LRR Deactivation Impact on NWS:** Deactivation of the LRRs will impact the NWS/RWDS weather information. If not already accomplished, coordination with the NWS is recommended. The impact of the loss of LRR weather on NWS should be examined.
- **Mode S Second Buy Decision:** This issue is focused on the Mode S second buy decision and the timeliness of the Mode S second buy sensors. In order to transition to a beacon-only system that provides coverage to 6000 feet, the sensors from the Mode S first buy, the ATCBI-4 and ATCBI-5 sensors, and at least 60 additional beacon sensors are required. It is recommended that the Mode S second buy be approved with a series of options and that the first option for 60 systems be implemented immediately.
- **Beacon-Only Transition Strategy:** The recommended transition strategy to a beacon-only system is a center-by-center strategy. This strategy assumes that the NEXRAD, WARP, and ISSS transition will have been completed at a center before the deactivation of the LRRs can begin. This ensures that essential weather services are provided center-wide. It is also assumed that the NPRM governing transponder usage is in place. Given these conditions, a center switch-over can be accomplished simply by "turning off" the primary radar input to the center. This approach eliminates the need to coordinate with multiple centers and sectors associated with the shutdown of a single radar. A sector-by-sector strategy is also possible and can be accomplished by simply turning off the primary radar input at the common console after center transition to NEXRAD weather products. Sector configuration in a center is not constant and sector-by-sector transition is therefore configuration dependent and is not recommended.

- Evolution to Stand-Alone Beacon:** Once a center has been commissioned to operate in a beacon-only mode, all enroute radars can be converted to a stand-alone beacon configuration providing the radar does not feed another center that has not yet been commissioned for beacon-only operation. This conversion to a stand-alone beacon mode of operation could be as simple as shutting down the primary radar transmitter and receiver; retaining the existing antenna structure, radome, rotary joints, and pedestal; and, switching the beacon into self-trigger mode. Alternatively, the stand-alone beacon conversion could involve installation of a new beacon antenna, rotary joint, pedestal, and possibly no radome. The rotation rate of the antenna could also be increased to 4-to-6 seconds similar to the terminal systems since the primary antenna is no longer needed. Decisions concerning this evolution must be made since the maintenance of the primary antenna system is a major cost element and new stand-alone systems require additional funds. A trade study is recommended to determine the least expensive approach.
- JSS Operation and Maintenance:** The issue in this instance is the need for the FAA to expend funds on a system after primary radar deactivation. The JSS radars may no longer be required for weather after the NEXRAD radar deployment, however, the beacon surveillance and perhaps its data link functions, provided that Mode S is used, will still be required. Thus, a study of the maintenance support is recommended.
- Mode S/Mode 4 Compatibility:** Concern has been expressed with respect to the compatibility of the operation of Mode S and Mode 4 at JSS sites. This concern requires resolution since the beacons that are located at the JSS sites are necessary for ATC services down to 6000 feet. A study and a test program is recommended.
- Fail Safe/Soft Beacon Modes:** The primary radar has been available as a backup to the beacon system in the event of an aircraft transponder failure or a ground beacon radar failure. Once the LRRs are deactivated, this backup will no longer be available. Other backup approaches such as procedural (non-radar) separation, overlapping coverage, redundant transponders, or possibly ADS/GPS as a backup system are possible. Fail safe/soft procedures must be in place prior to transition to the beacon-only system. NAS-SR-1000 classifies aircraft detection and identification as an essential service while aircraft separation is a critical service. Availability of beacon coverage is therefore specified at a minimum availability of 0.999. Development of fail safe/soft beacon operational modes is recommended.
- ADS/GPS Data Link:** The present design for the ADS/GPS system includes the Mode S data link as an essential design component. The Mode S transponder "squitters" the aircraft-derived GPS position and is received by a ground-based Mode S system. This ground-based system could consist of a six-segment phased array antenna as Lincoln Laboratory is presently recommending. The link margin in this design is at issue, but more important, the transition to a complete Mode S ground system compatible with ADS/GPS is being considered. This being the case, the Mode S second buy and the end-state configuration of the beacon-only system could have a significant impact on the transition

to ADS/GPS. An early decision concerning the evolution to an ADS/GPS system could influence the composition of beacon radars in the beacon-only en route system.

4.1.2 LRR Deactivation Recommendations

The following set of recommendations represent a step-by-step approach to the implementation of the LRR deactivation decision.

1. Examine, modify, and initiate new CIP, R, F&D and Operations programs required for, or impacted by, the deactivation decision. The indefinite cancellation of the ARSR-3 Leapfrog Program coupled with a lack of an MNS that would identify additional funds to ensure that the transition to a beacon-only system will be funded, is a critical element for the estimated transition data.
2. Launch new programs such as coverage studies and the en route beacon stand-alone antenna immediately so that timely funding adjustments can be made.
3. Start a cost/benefit study to confirm the cost/benefit advantage of the deactivation decision.
4. Use deactivated LRRs to help sustain operational LRRs.
5. Examine the relocation of NEXRADs for improving coverage and the addition of RMMS for improved availability. Once a center has changed over to all NEXRAD weather, it becomes a candidate for beacon-only operation.
6. Coordinate NEXRAD implementation schedules with the schedule for transition to a beacon-only system. This could accelerate the transition to beacon-only operations to 1999 and provide a one-year savings of LRR support costs.
7. Accomplish beacon coverage to 6000 feet using an integrated terminal and en route beacon system
8. Initiate a Mode S second buy with options. The first option should be for the additional beacons required to achieve 6000-foot coverage. Later options should be for the eventual conversion of all beacon radars to stand-alone Mode S facilities.
9. Changeover to beacon-only operation using a center-by-center strategy.
10. Begin the development of ATC rules and procedures for beacon-only operations including fail safe and fail soft considerations.
11. Introduce rule making for transponder carriage in a timely fashion so that aircraft are equipped by 1999 and be compatible with early transition to beacon-only operations.

12. Evolve to a JSS system composed exclusively of ARSR-4 and ARSR-3 radars. Presently, the system of 48 JSSs contains some older radars that can be eliminated. This will result in improved JSS performance and reduced maintenance costs.
13. Establish a stand-alone en route beacon system goal but do not make the certification of beacon-only operation at a center contingent deployment of stand-alone beacon facilities. Evolve to this configuration over time.
14. Provide beacon system backup with overlapping coverage and eventually with ADS/GPS. This will permit a graceful evolution to ADS/GPS as the primary surveillance system of the future.
15. Operate and maintain the JSS radars until it can be shown that it is cost effective to establish additional stand-alone beacons that duplicate the beacon coverage available from the JSS radars.

4.2 CONCLUSIONS

Deactivation of the LRRs is feasible and cost-effective compared to replacement and maintenance of primary radars, and in particular, a transition to Mode S will help in the future, when the evolution/transition of the entire surveillance system to satellites is considered. Random failure of LRR cannot be tolerated since this would be disruptive to air traffic control and would result in the unavailability of essential weather services. The LRRs must be sustained and supported until an orderly evolution to NEXRAD and beacon-only capabilities are available.

Approximately 60 additional beacon radars are required to achieve coverage down to 6000 feet. Both NEXRAD and beacon radar locations must be modified to satisfy the 6000-foot requirement. NEXRAD will also have to be retro-fitted with RMM in order to meet the availability requirements of the NAS-SR-1000 document.

The NEXRAD/WARP/ISSS and the procurement of additional beacons are the pacing items associated with deactivation of the LRRs. Transition to a beacon-only system can only take place after the NEXRAD weather products are available to the controller on a center-wide basis, provide the required airspace coverage, and satisfy operational requirements.

The total funds required for transition to a beacon-only capability are in excess of \$2.0B. Programs to extend the life of the LRRs so that orderly transition can occur will cost about \$90.5M. Operations and support costs for the FAA LRRs until 2002 are approximately \$492.0M with an additional \$272.4M for the JSSs. The AN/FPS-117 radars are essential to air traffic operations in Alaska because of their beacon capabilities and \$97.8M is required for their support. The total costs directly attributable to the deactivation decision are however \$138.6M yielding a benefit-to-cost ratio in excess of 10.

APPENDIX A

Decision Memorandum

ISSUE: Deactivate long-range (primary) radars (LRR) in the en route environment.

BACKGROUND: LRR's were the first type of radar used in air traffic control starting in the early 1950's. It could only provide the aircraft's horizontal position (azimuth) and range relative to the radar. Until beacon type radars were available, the controller received the aircraft's altitude by voice, and identified the aircraft by having the pilot make turning maneuvers observable on his display.

The LRR's also provide for the symbolic representations of weather on the controller's display ("H"'s for heavy and slash marks for medium). A new weather radar superior to the LRR has been developed by the National Weather Service known as next generation weather radar (NEXRAD). The NEXRAD will replace the LRR as the weather source in the en route airspace.

There are currently 113 LRR's installed in the National Airspace System. Thirty-eight of these are being replaced with a new joint civil/military use radar, the ARSR-4. After these ARSR-4's are installed, there will be approximately 84 LRR's remaining in the en route environment. Some of these radars are over 35 years old and are no longer cost-effective to maintain. Their continued use will necessitate replacement at an estimated cost of \$1.4 billion.

DISCUSSION: A study was conducted by the Martin Marietta Corporation under the joint sponsorship of AXD and AXO in 1990. This study found that 97% of the IFR aircraft in the en route airspace were beacon equipped. The study concluded there were no significant safety impacts or cost benefits to retaining the LRR's after NEXRAD was available.

Considering the staggering replacement costs and the fact that most (97%) of the IFR aircraft in the en route airspace are beacon equipped and that NEXRAD will soon be available for weather brings the continued use of the LRR's into serious question.

DECISION: Deactivate the LRR's when NEXRAD weather products are provided to the controller. This will save the expenditure of approximately \$1.4 billion.

In conjunction with this decision, AXO will issue an NPRM requiring transponders on all IFR flights at all altitudes and VFR flights above 6,000 ft. after 1997

AXO Concur: _____

AXD Concur: _____

AXO Nonconcur: _____

AXD Nonconcur: _____

Date: 2/20/93

Date: 4/17/93

APPENDIX B

NAS-SS, -SR Surveillance Recommendations

NAS-SS-1000, Para. 3.2.1.2.7.4, Surveillance Coverage

The NAS shall provide independent surveillance coverage for the entire area of NAS responsibility, as follows: Exceptions to these requirements are permitted over areas where extraordinary measures would be required to provide coverage. In those areas, coverage shall be provided based upon consideration of the cost of providing surveillance and of air traffic in the area.

- a. En route non-cooperative: Surveillance coverage shall be from 6000 feet MSL up to and including 20,000 feet mean sea level (MSL) over non-mountainous terrain, and from 6000 feet MSL or minimum en route altitude (MEA), whichever is higher, to 20,000 feet in mountainous terrain;
- b. En route cooperative: Surveillance coverage shall be from 6000 feet MSL up to and including 60,000 feet over non-mountainous terrain, and from 6000 feet MSL or MEA, whichever is higher, to 60,000 feet MSL in mountainous terrain;
- c. Terminal cooperative/non-cooperative: Surveillance coverage shall be from ground level up to and including the altitude as authorized by Letters of Agreement that define area of control jurisdiction for terminal area;
- d. Sovereignty (ADIZ and Alaskan Portion of DEWIZ): Surveillance coverage shall be from ground level to +30 degrees relative to an earth-tangential plane at the sensor site up to and including 100,000 feet MSL and to a maximum surface range of 200 nm, for all terrain;
- e. Airport surface: Surveillance coverage shall be a surface range from 500 feet, up to and including 12,000 feet from the sensor.

NAS-SR-1000, Para. 3.1.1.A.3, Weather Requirements

- B. Information concerning weather conditions that are potentially hazardous to aviation shall be given priority as to acquisition and dissemination. Hazardous weather shall include the following weather conditions:
 1. Turbulence
 2. Icing
 3. Thunderstorms

- C. The NAS shall be capable of providing pictorial displays of real-time weather data (e.g., radar) to users and specialists.
- 3. Real time weather information shall be provided to users in a form suitable for pictorial display on user-supplied compatible devices on the ground and in the cockpit.

NAS-SR-1000, Para. 3.8.1.A, Specific Requirements

- A. NAS services to the user/specialist shall be categorized according to the severity of impact of loss of that service on safe separation and control of aircraft. These NAS services as required by this document are categorized in Table 3-6. These categories are:
 - 1. **CRITICAL.** Functions or services which, if lost, would *prevent* the NAS from exercising safe separation and control over aircraft.
 - 2. **ESSENTIAL.** Functions or services which, if lost, would *reduce* the capability of the NAS to exercise safe separation and control over aircraft.
 - 3. **ROUTINE.** Functions and services which, if lost, would *not significantly degrade* the capability of the NAS to exercise safe separation and control over aircraft.
- B. The availability goal for function and service to the user/specialist is expressed as the ratio of the total time the service is provided to the user/specialist to the maximum available operating time. Service availability shall not be less than that provided by existing capabilities.

NAS-SR-1000, Para. 3.8.1.B

1.	Critical Services	.99999
2.	Essential Services	.999
3.	Routine Services	.99

- C. No single failure of equipment, system, installation or facility shall cause loss of service to the user/specialist.
- D. The goal for the single loss of service to a user/specialist shall not exceed the duration shown below:

1.	Critical Services	6 seconds
2.	Essential Services	10 minutes
3.	Routine Services	1.68 hours

- E. The frequency of occurrence goal for any loss of service shall not exceed one per week.

Table B-1. Surveillance System Requirements

Document	Aircraft Surveillance Requirements	Weather Requirements	Other Applicable Requirements
SR-1000	2.5 Air Defense and Law Enforcement Surveillance 3.2.3 Aircraft Separation 3.2.4 Outside Surveillance Coverage 3.2.10 Support of Military Operations	3.1.1 Weather Information (Strategic) 3.2.3D Aircraft Separation 3.2.6 Weather Avoidance 3.3.3 Weather Advisories	3.7 Maintenance and Support 3.8 System Effectiveness
DD-1000	<ul style="list-style-type: none"> • Surveillance Network Data Flow (III-25) • Surveillance Facilities (V-67) 	<ul style="list-style-type: none"> • Non-Radar Weather Sensor Data Flow (III-15) • PIREP Data Flow (III-19) • Radar, Satellite, and NWS Weather Data Flow (III-21) • FSDPS (IV-27) • RWP (IV-33) • WCP (IV-37) • MWP (IV-41) • AFSS (IV-63) • Weather Sensing Facilities (V-3) 	<ul style="list-style-type: none"> • RMMS Network Data Flow • RMMS (VII-3) • MCC (VII-25) • System Support Facilities (VII-33) • Training Facilities (VII-49)
SS-1000 VOL-I	3.1.1.1.1.7 Surveillance 3.2.1.1.7 Surveillance General Requirements 3.2.1.2.7 Surveillance Performance Characteristics	3.1.1.1.1.4 Weather 3.2.1.1.4 Weather General Requirements 3.2.1.2.4 Weather Performance Characteristics	3.1.1.1.1.9 RMM 3.2.1.1.9 RMM General Requirements 3.2.1.2.9 RMM Performance Characteristics
SS-1000 VOL-II		3.1.2.5 Weather Processing Subelement 3.2.1.5 Weather Processing Subelement	3.1.2.3 Automated Flight Service Element 3.2.1.3 Automated Flight Planning Subelement
SS-1000 VOL-III	3.1.2.1 Surveillance Subelement 3.1.3.1 Surveillance Subelement 3.2.1.1 Surveillance Subelement	3.1.2.2 Weather Sensing Subelement 3.1.3.2 Weather Sensing Subelement 3.2.1.2 Weather Sensing Subelement	
SS-1000 VOL V			Maintenance and Operations Support Element
SS-1000 Appendix II	20.12 Surveillance Facility Set	20.13 Weather Facility Set	20.15 RMMS

APPENDIX C

Radar Performance Characteristics

This appendix provides the performance characteristics for the following radars:

- ARSR-4, System Specification FAA-E-2763b, May 6, 1988;
- AN/FPS-117, Radar Reference Manual, Volume II, MITRE
- ARSR-1, 2, 3, Radar Reference Manual, Volume I, MITRE;
- FPS-20 Series, Radar Reference Manual, Volume I, MITRE;
- ATCBI, U.S. National Standard for the IFF Mark X (SIF) Air Traffic Control Radar Beacon System Characteristics (ATCRBS), FAA Order 1010.51A;
- Mode S, Mode S Beacon System: Functional Description, Project Report, ATC-42, 29 August 1986;
- NEXRAD, WSR-88D Radar Characteristics, Doran Platt, National Weather Joint Program Office, Silver Spring, Maryland.

C1. ARSR-4 Air Route Surveillance Radar

A long-range three-dimensional surveillance radar is in production and is currently being tested. This radar is intended for joint use with the military. The radar will be located around the perimeter of CONUS as shown in Figure 2-4 and 4a and other designated areas outside the U.S. The radar coverage is shown in Appendix D and it provides coverage from the ground level up to 100,000 feet in elevation. The coverage range of the ARSR-4 is 250 nautical miles.

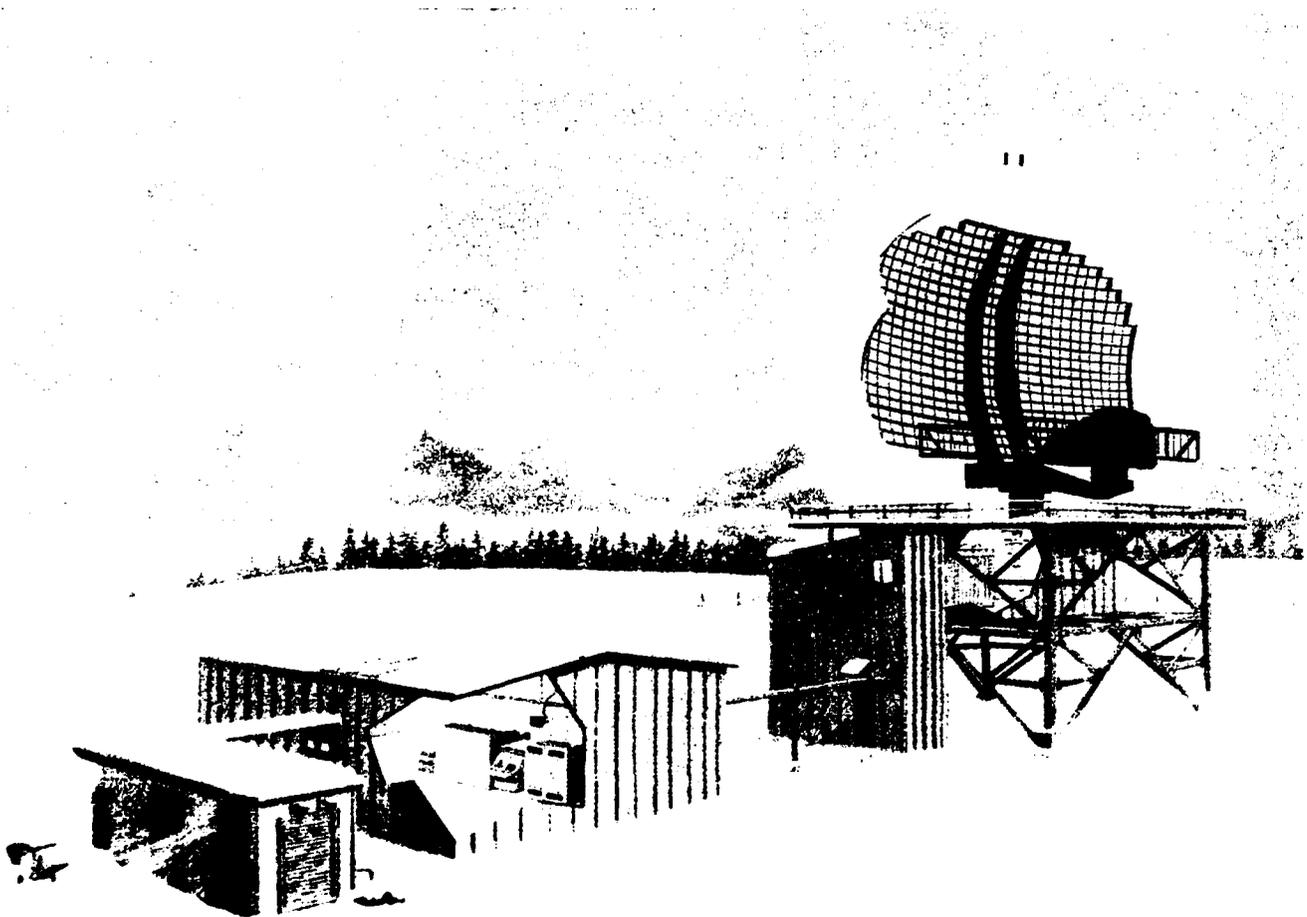


Figure C-1. ARSR-4 Surveillance Radar

Specified Accuracies

<i>Azimuth = 0.176 degrees RMS</i>	<i>PD=80%</i>
<i>Range = 1/16 nautical mile RMS</i>	<i>PD=80%</i>
<i>Height= 3000 FT RMS</i>	<i>2.2 sq. meter; 5-175 nm;</i>
	<i>- 1.0 degrees/+0.2 degrees;</i>
	<i>0+ 20 degrees;</i>
<i>Air sovereignty airspace</i>	<i>0.1 m² (limited to 92 nm range)</i>
<i>False Reports per scan =</i>	<i>194 average over 10 scans under all conditions;</i>
<i>Availability = 0.997.</i>	

Specified Resolution While Maintaining Specified Accuracies

<i>Azimuth =2 degrees</i>	<i>Two 10 sq. meters; 5-200 nmi;</i>
	<i>PR=90%;</i>
<i>=1.5 degrees</i>	<i>Two 2.2 sq.meters;100 nm;</i>
	<i>PR=50%;</i>
<i>Range = 1/8 nautical mile</i>	<i>Two 10 sq.meters; 5-200 nm;</i>
	<i>PR=90%;</i>
<i>Antenna Beamwidth Requirement</i>	
<i>Azimuth =1.4 degrees</i>	
<i>Elevation varying from 1.8 degrees</i>	
<i>Capacity = 800 targets</i>	
<i>Receiver = Doppler and normal channels; parallel channels are allocated for target and weather detection.</i>	

C2. AN/FPS-117 Surveillance Radar

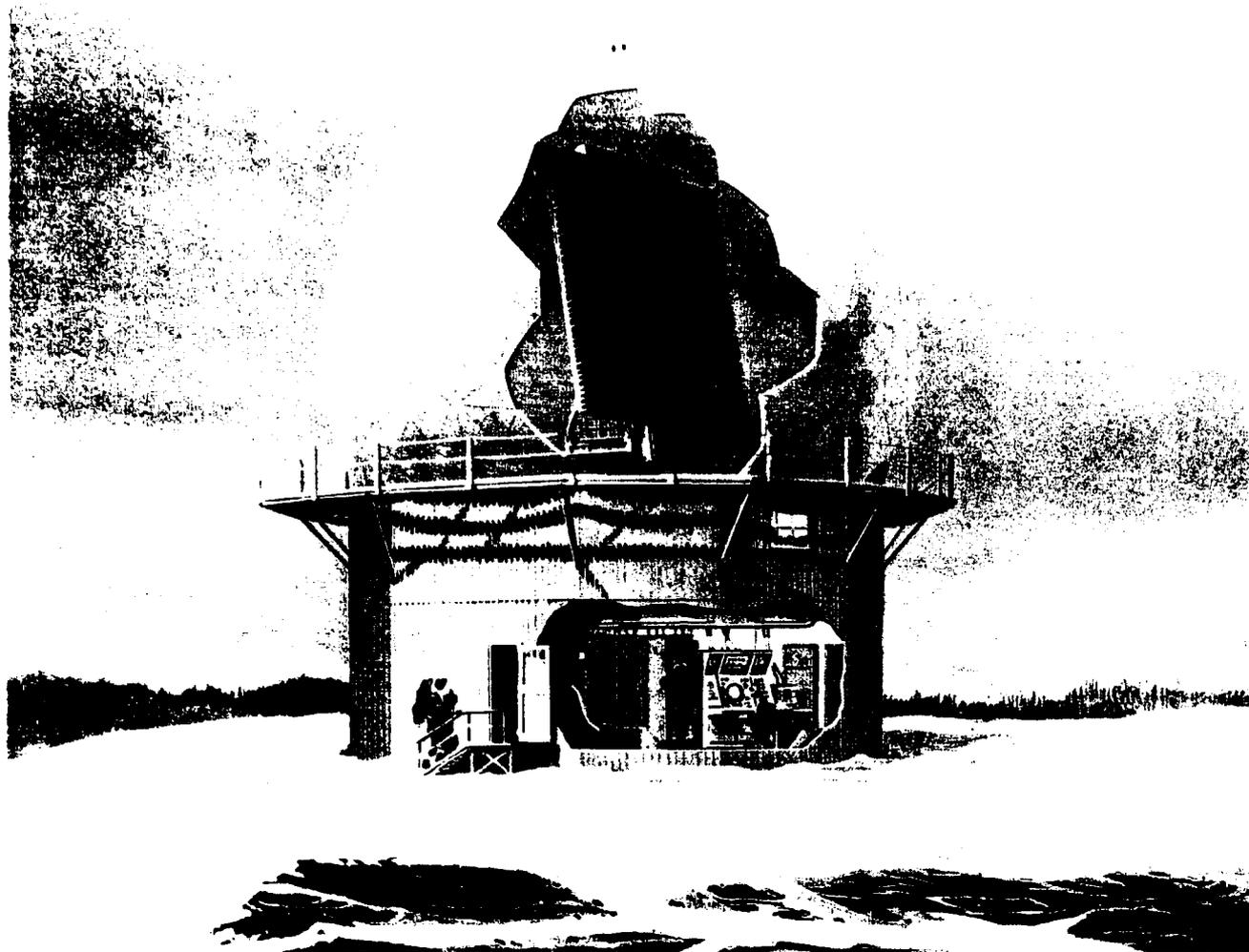


Figure C-2. AN/FPS-117 Surveillance Radar

Accuracy

Range = 0.125 nm to 160 nm

Azimuth = 0.18° rms to 160 nm

Height = 3000 feet to 100 nm

6000 feet from 100 to 160 nm

Resolution

Range = 0.25 nm to 100 nm

Azimuth = 2° to 100 nm

Transmitter

Solid State - distributed on array

Peak Power = 24.75 kW

Average Power = 2.94 to 3.78 kW

Pulse width = 51.2 μs for short range

409.6 μs for long range

C3. ARSR-1,2,3 and FPS-20 Series

Long-range two-dimensional surveillance radars within CONUS interior providing service volume within 6,000 to 20,000 feet above MSL or MEA and in the range of 250 nautical miles.

Accuracy Requirements

Range = 820 FT RMS; 2 sq. meters, Swerling I
Azimuth = 0.2 degrees RMS; PD=0.8
Altitude Coverage Limit = 61,000 Ft; FA=10
Range Coverage Limit = 200 nautical miles;
Receiver = Parallel and interleaved

C4. ATCRBS/Mode S Air Traffic Control Radar Beacon

Accuracy Mode S

Range = 25 feet (1 σ) 30 feet bias
Azimuth = 0.06 degrees (1 σ) 0.033 degrees bias
Altitude = 125 feet (2 σ), based on BARO readings
Capacity = 700 targets per Scan
False Reports = 4 per scan within any target condition
Delivery Reliability = > 0.99

Resolution

Range + 344 feet RMS
Azimuth + both targets assumed to exist in the same range cell 1/145 nm (0.085 μ s) 1 σ

C5. NEXRAD Technical Data

Frequency = 2700 MHz to 3000 MHz *Fast Scan: 16 modes, 14 levels*
Peak Power = 750 kW *Average Rotation Rate 3.6 rpm*
Pulse widths + 1.75 μ s and 4.7 μ s *Antenna beamwidth: 0.95 $^\circ$*
Dynamic range = 93 dB
Noise Temperature = 450 $^\circ$ K
Band width = 0.79 MHz

APPENDIX D

En Route Primary and Beacon Radar Surveillance Coverage Diagrams

Primary radar coverage diagrams were created with CHRISTI, a radar coverage analysis model, which uses Defense Mapping Agency World Vector Shoreline and Digital Terrain Elevation Data and the Mercator Conformal Cylindrical Projection.

Radar surveillance coverage diagrams were created by John Prots, Senior Scientist, ANSER, Suite 800, 1215 Jefferson Davis Highway, Arlington, Virginia 22202.

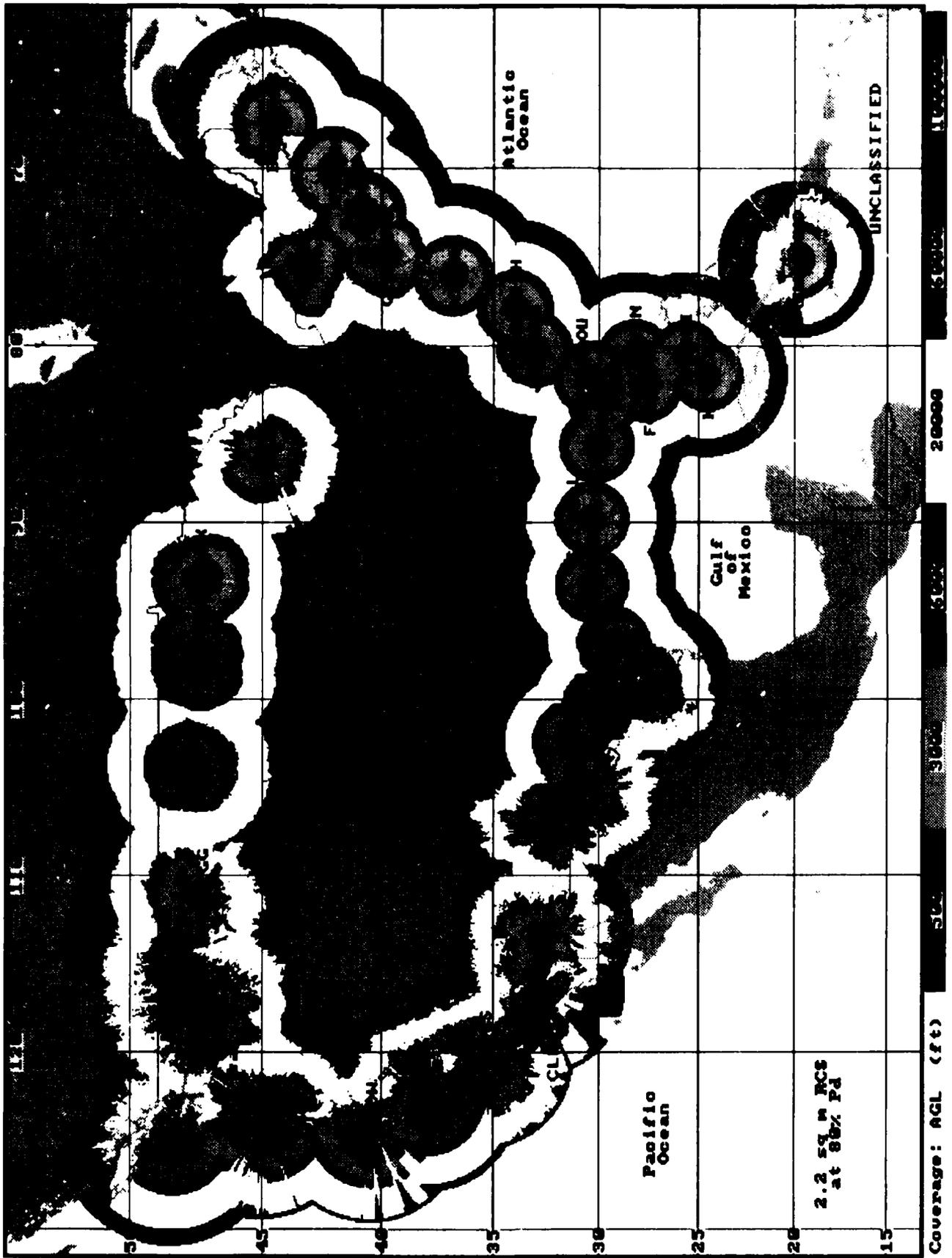


Figure D-1. ARSR-4 Surveillance Coverage at All Altitudes

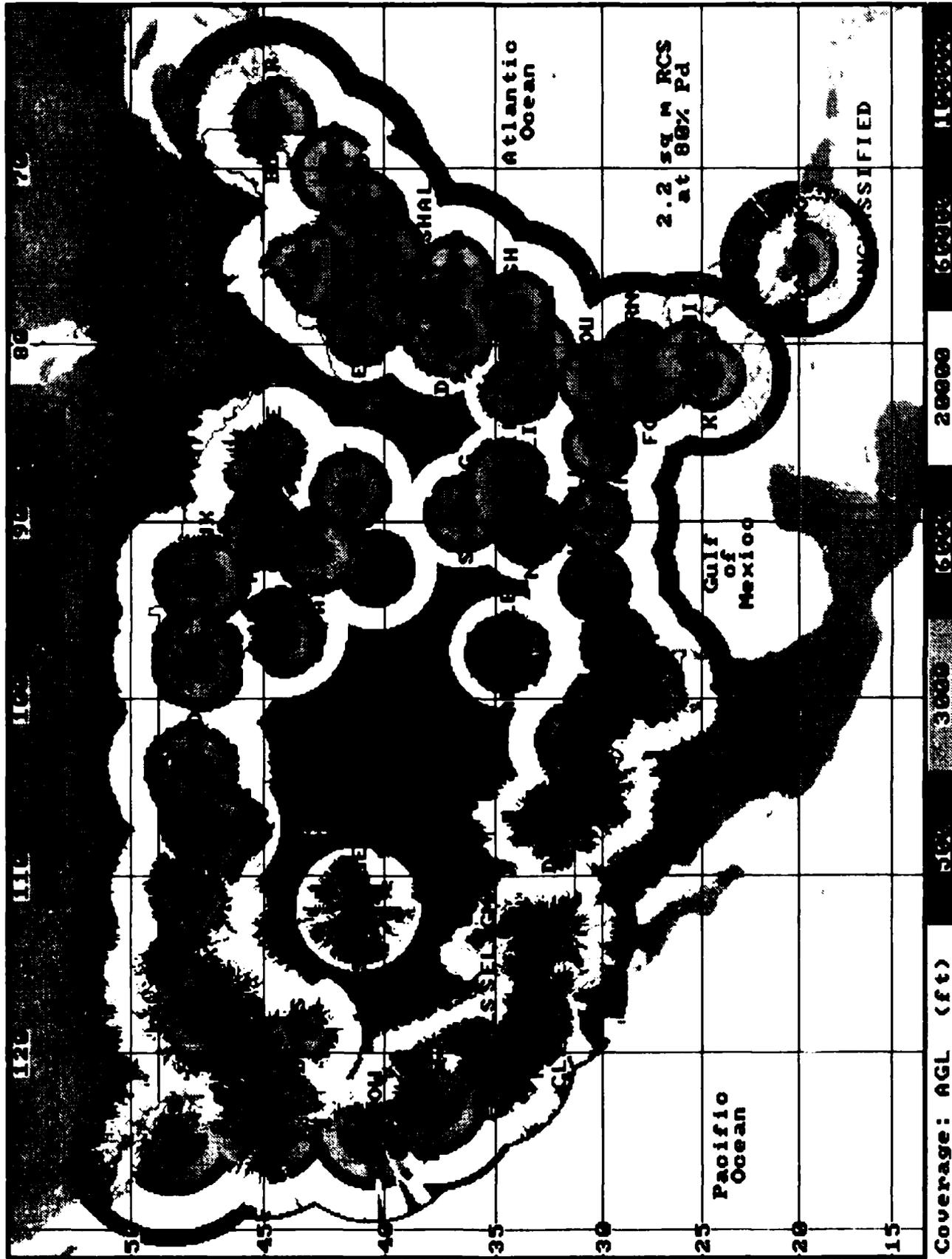


Figure D-2. ARSR-4 and ARSR-3 Surveillance Coverage

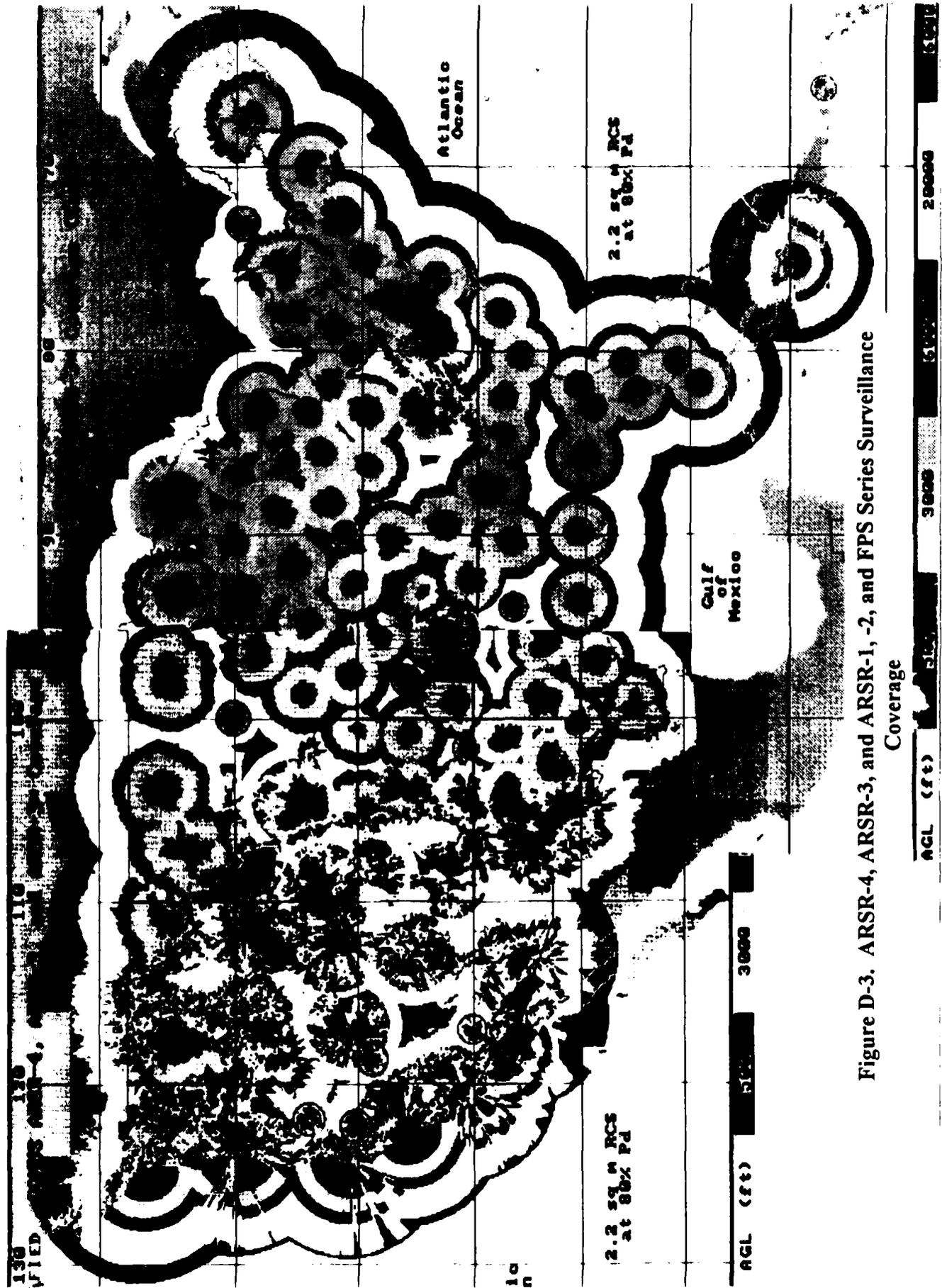


Figure D-3. ARSR-4, ARSR-3, and ARSR-1, -2, and FPS Series Surveillance Coverage

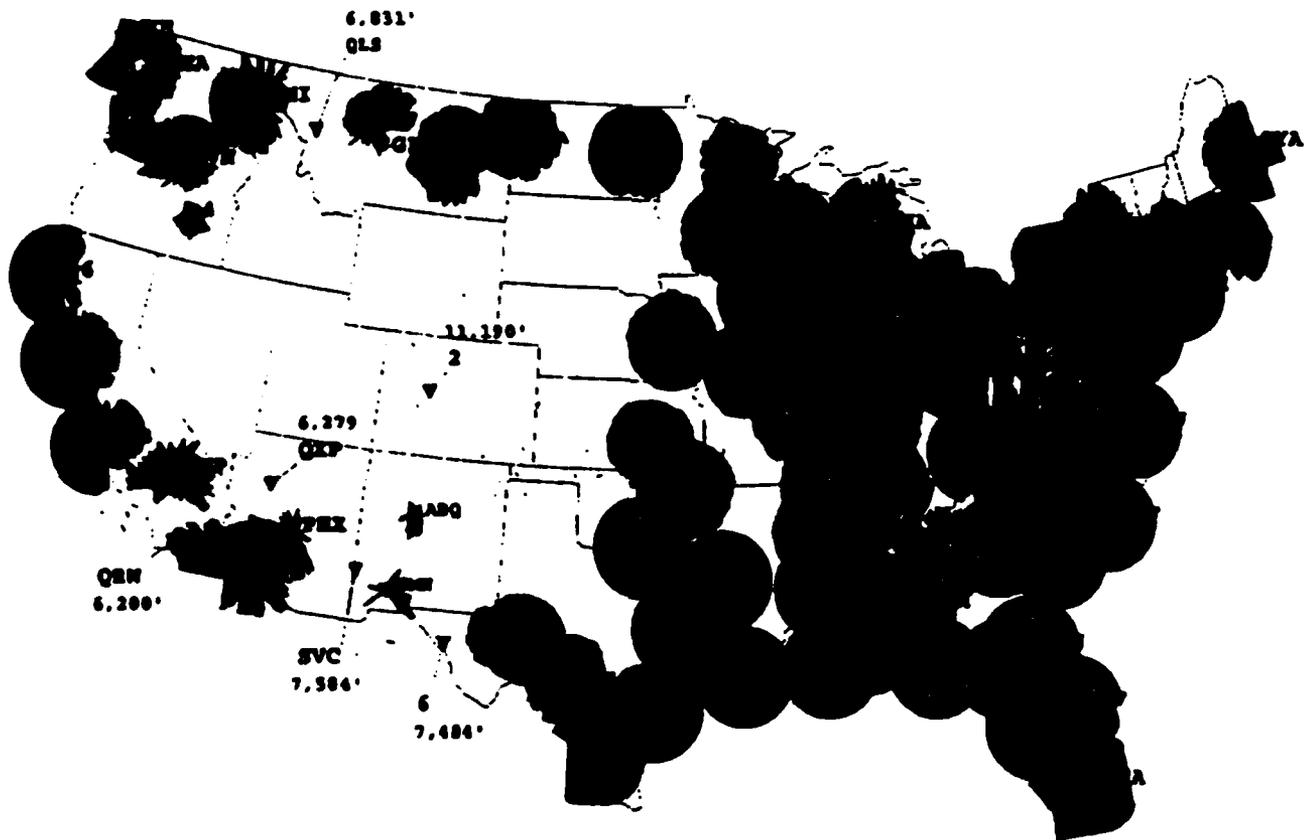


Figure D-4. Beacon Surveillance Coverage¹
Coverage for all beacon radar sites at 6000 feet MSL - using 100nm for terminal and en route Mode S, 50 nm for terminal ATCRBS, and 100nm for non-Mode S en route sites.

¹ Martin Marietta data, October 13, 1993.

APPENDIX E

NEXRAD Coverage and Location Diagrams

Primary radar coverage diagrams were created with CHRISTI a radar coverage analysis model which uses Defense Mapping Agency World Vector Shoreline and Digital Terrain Elevation Data and the Mercator Conformal Cylindrical Projection.

All diagrams were created by John Prots, Senior Scientist, ANSER, Suite 800, 1215 Jefferson Davis Highway, Arlington, Virginia 22202.

NEXRAD location and status maps and radar characteristics were provided by Doran Platt, National Weather Joint Program Office, Silver Spring, Maryland.

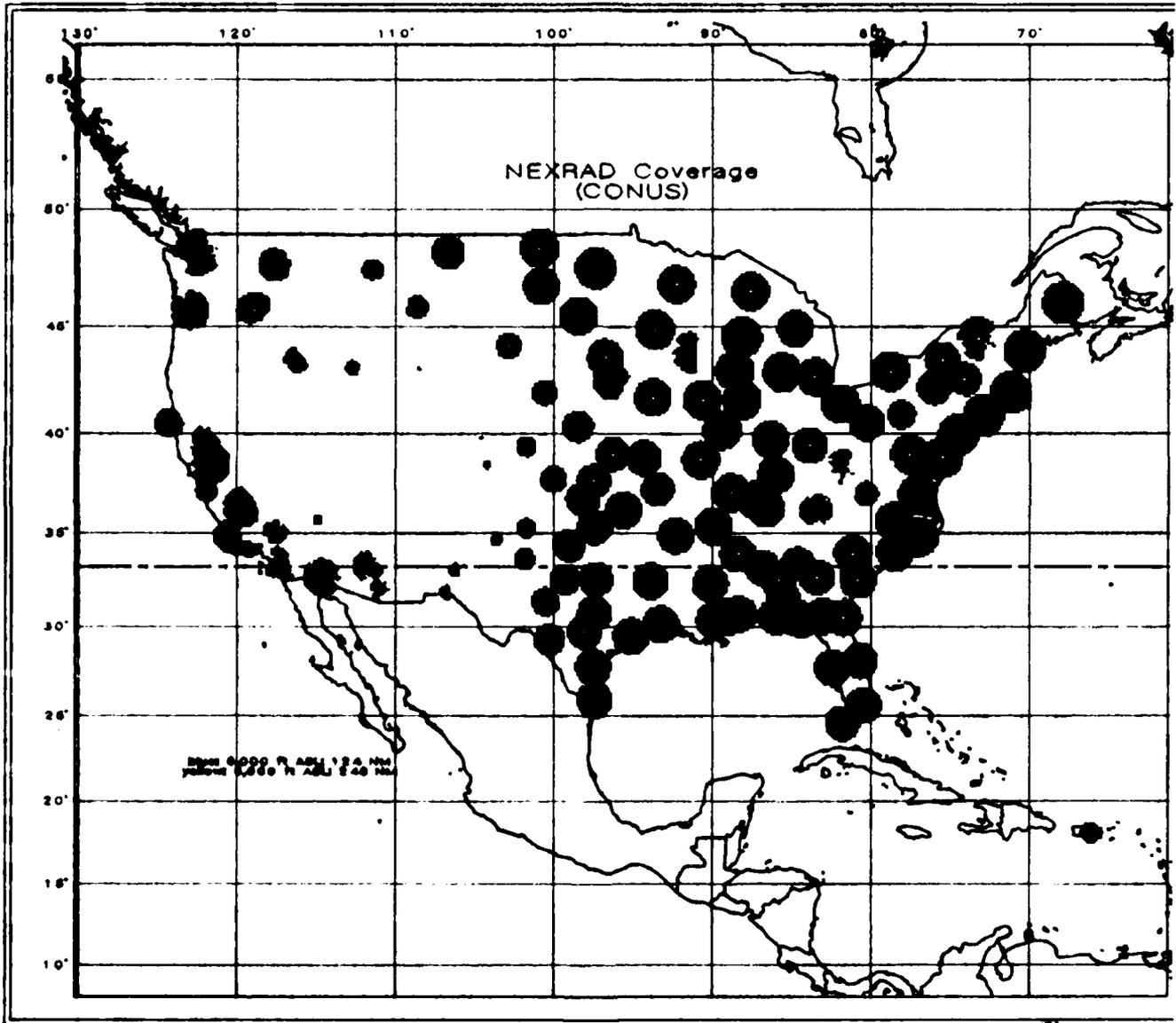


Figure E-1. Weather Coverage Above Sea Level at 6000 Feet

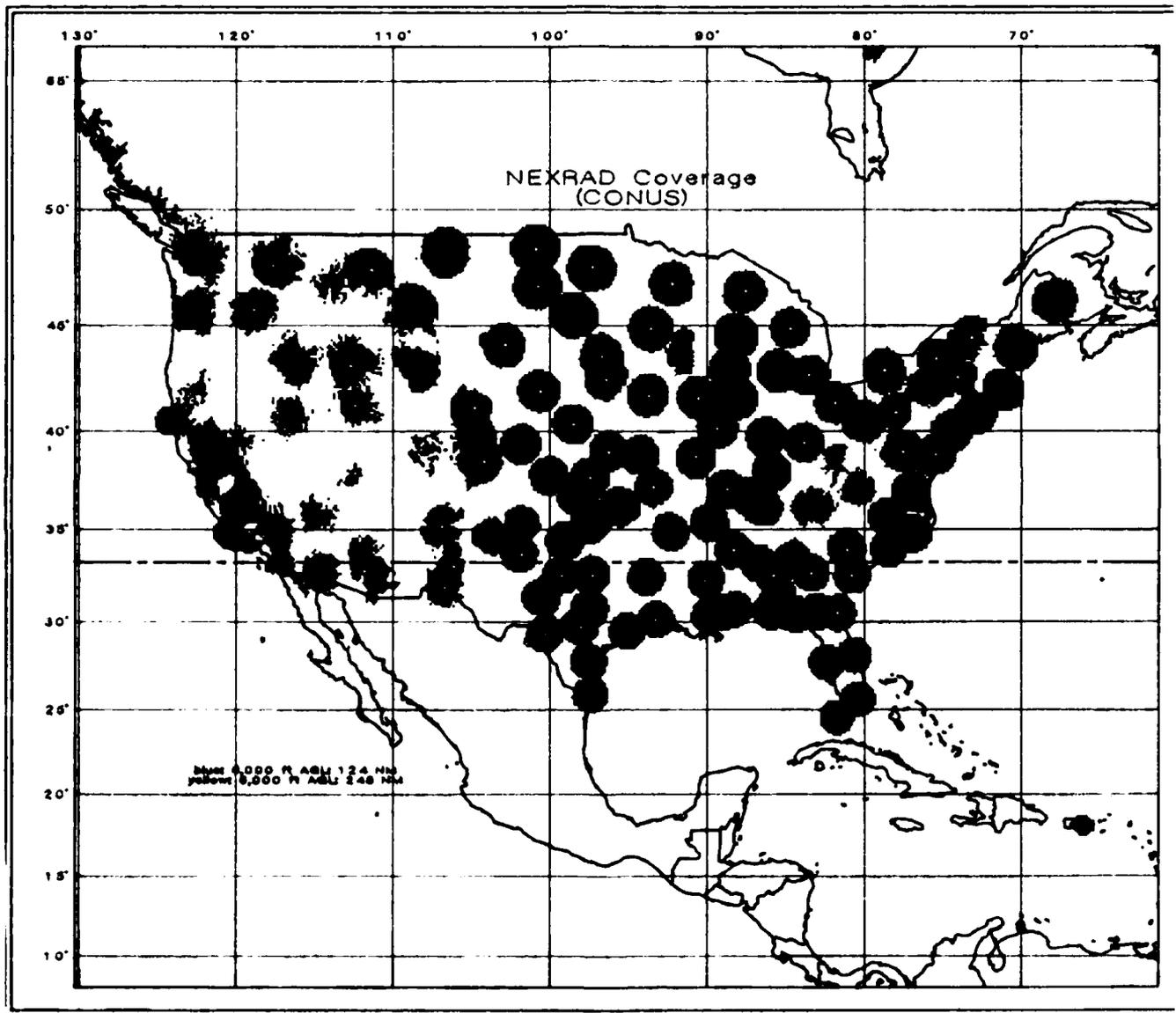


Figure E-2. Weather Coverage Above Ground Level at 6000 Feet

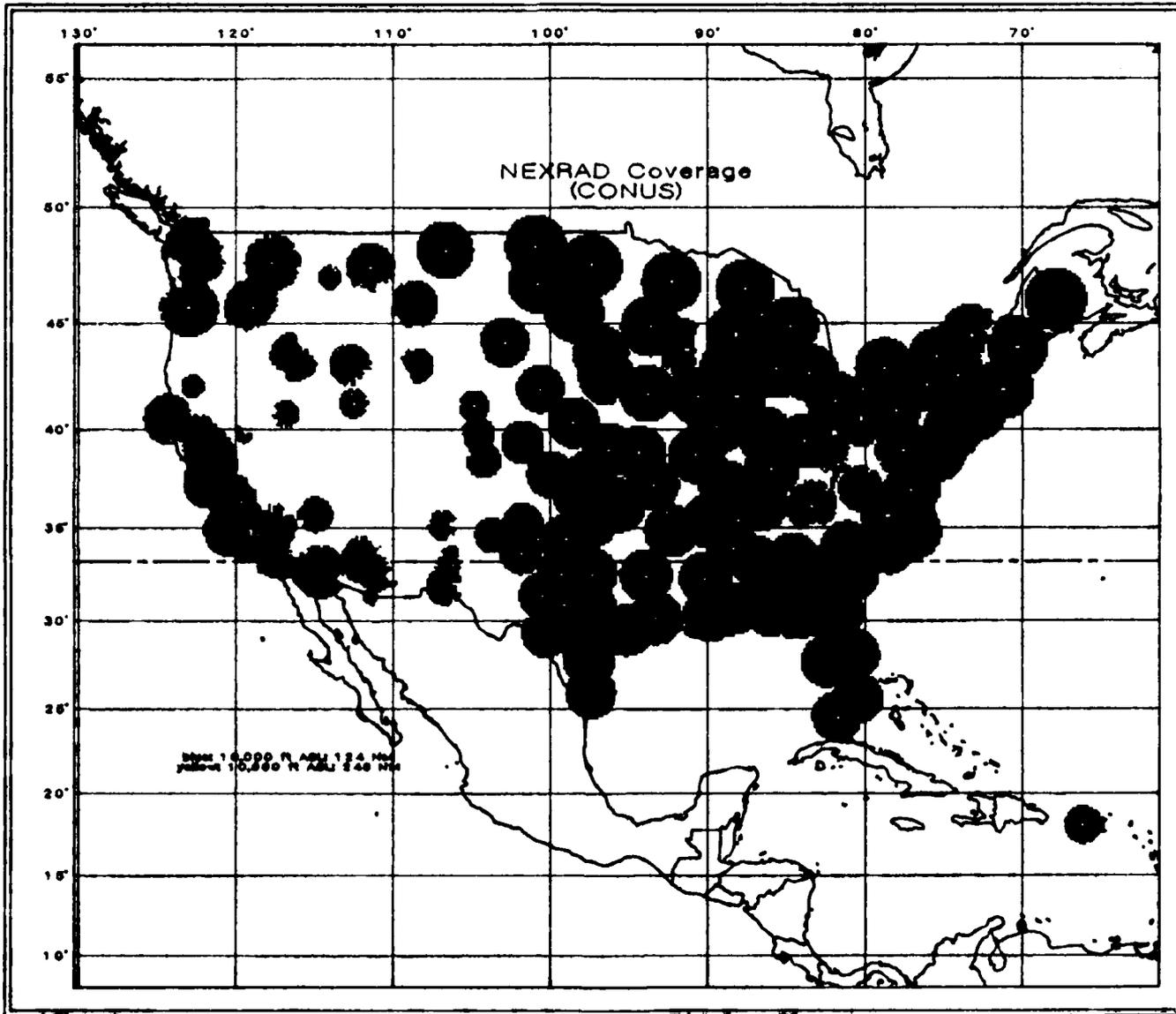


Figure E-3. Weather Coverage Above Sea Level at 10,000 Feet

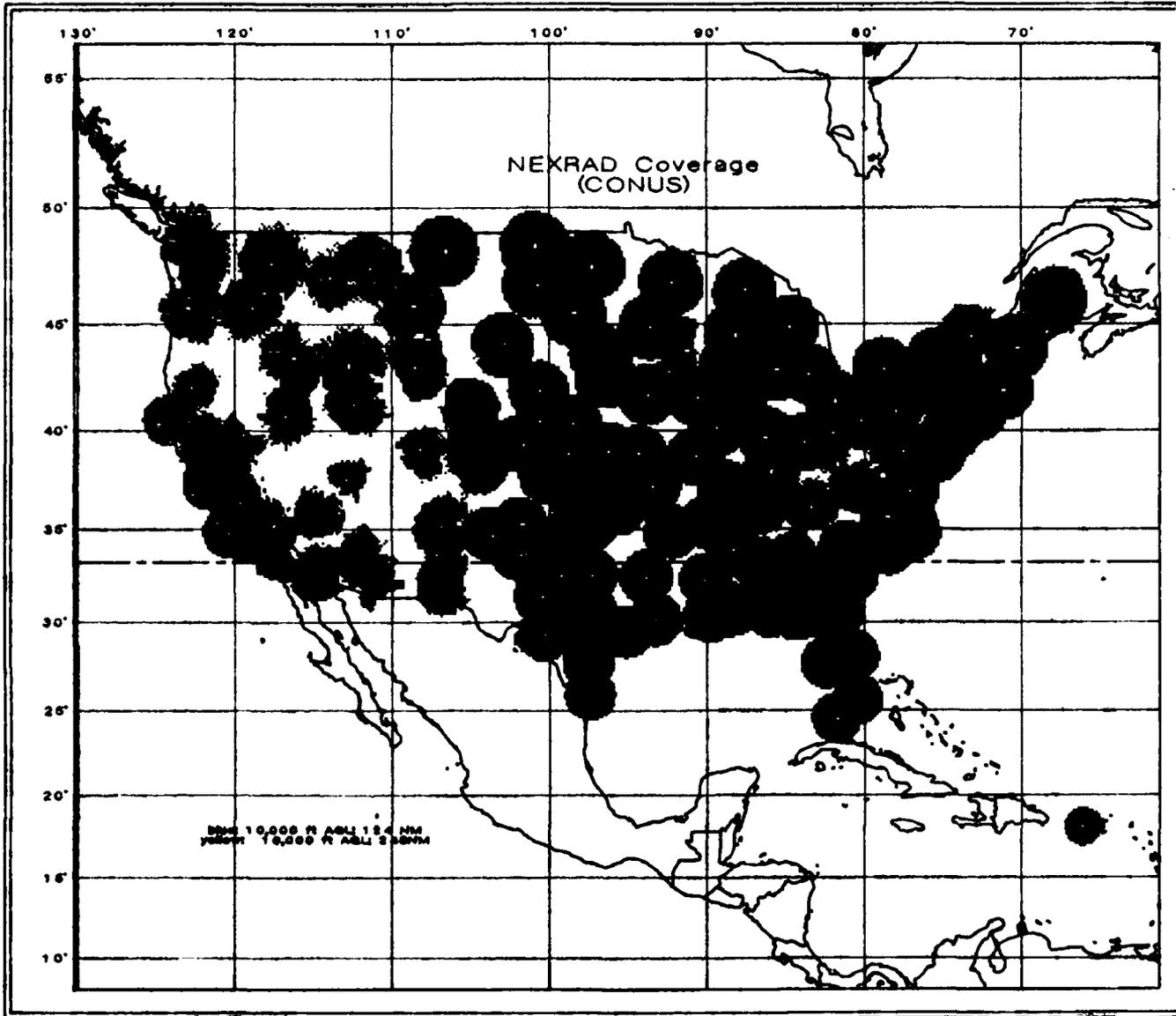


Figure E-4. Weather Coverage Above Ground Level at 10,000 Feet

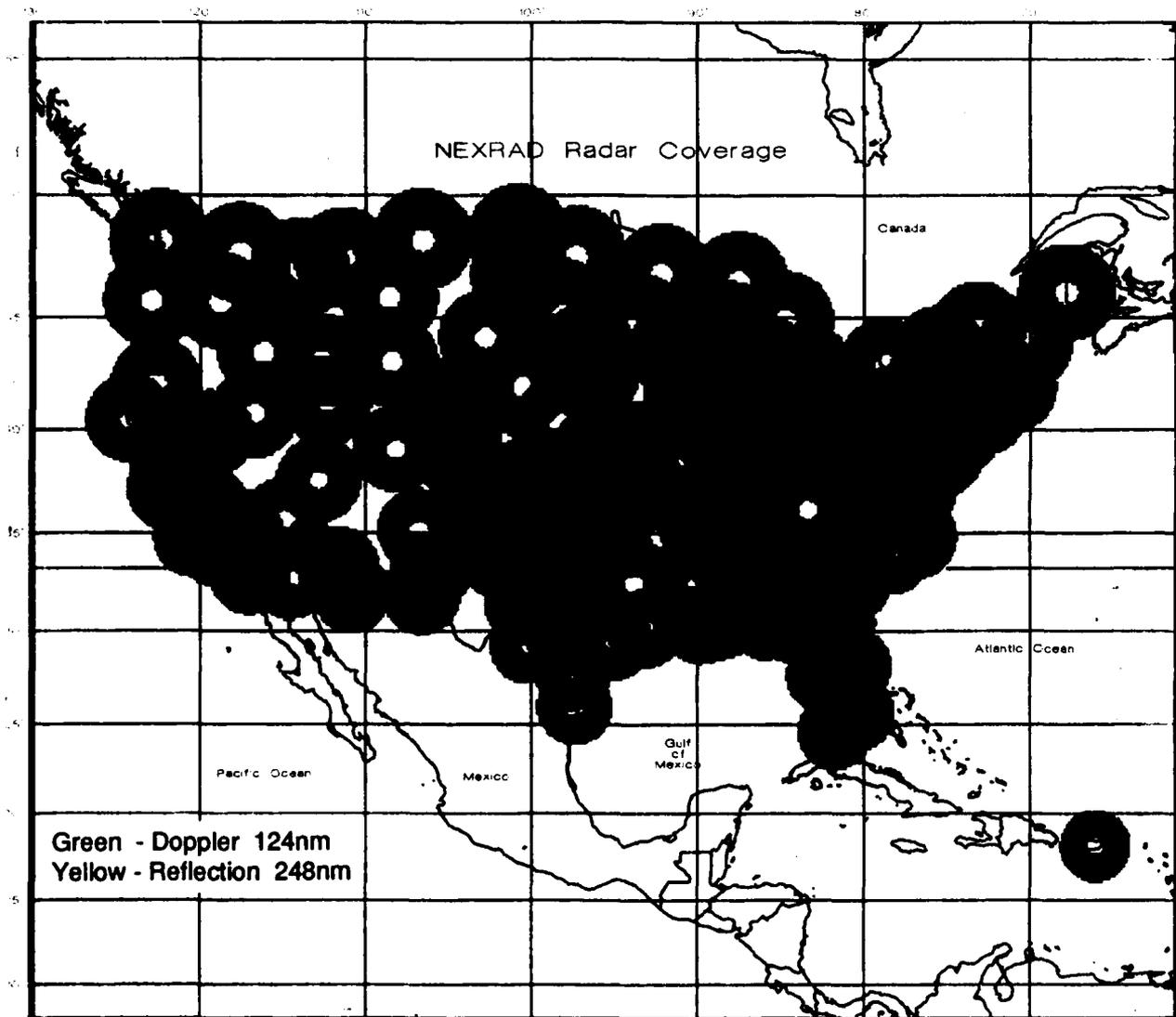


Figure E-5. Weather Coverage Above Ground Level at 60,000 Feet

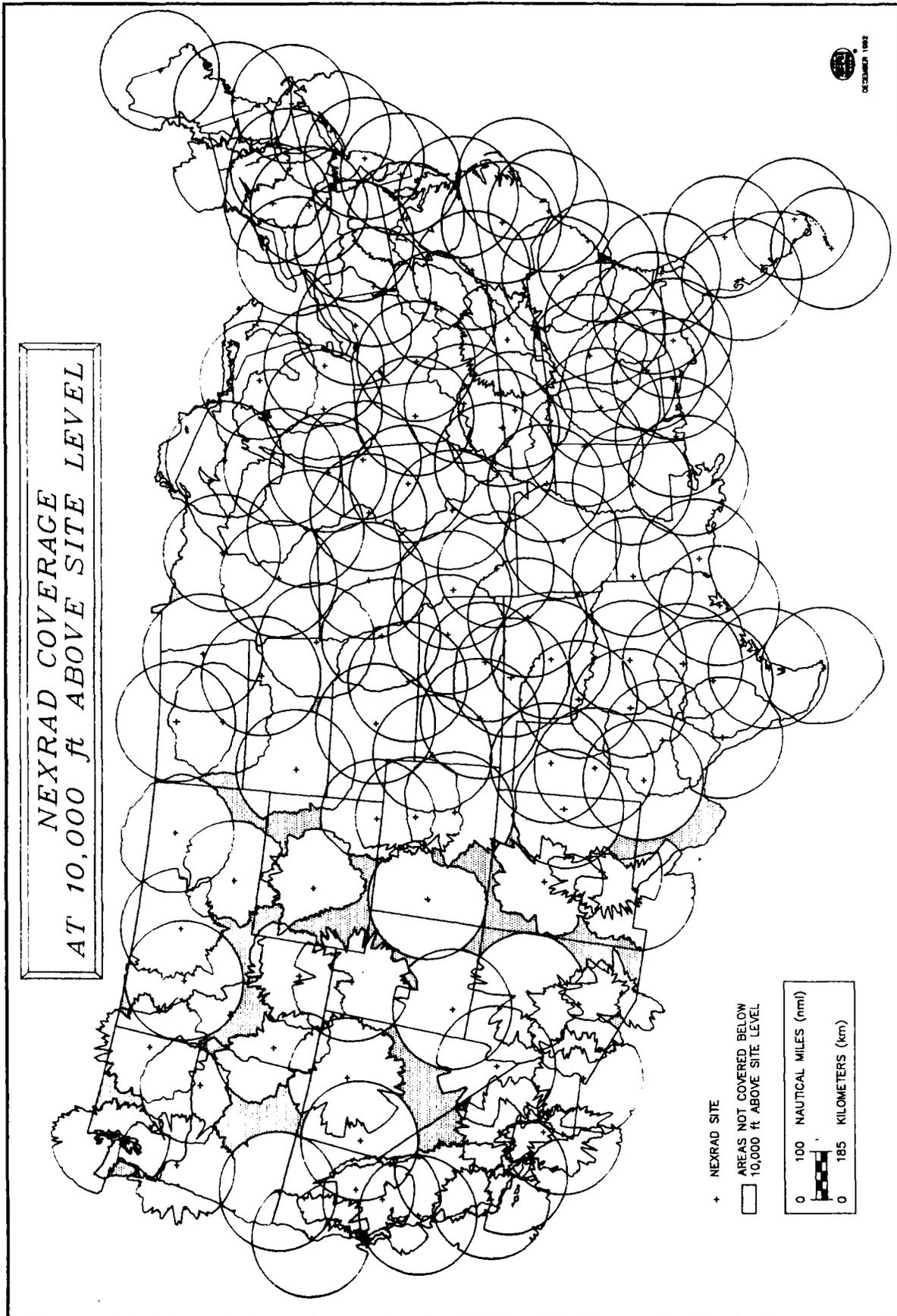


Figure E-6. An SRI NEXRAD Coverage Chart at 10,000 Feet Above Site Level

APPENDIX F

Cost Estimates

The cost estimates contained in this appendix have been derived from the base data presented in Appendix L of the Martin Marietta study of long-range radar disestablishment conducted in 1990. All applicable figures will, however, be duplicated in order to provide the reader with sufficient information to understand the costing methodology employed. For purposes of this study, all estimates will be calculated in constant 1994 dollars.

The first figure, Figure F-1 presents the overall operations and support costs and cost trends from 1989 through 1992 in "Then-Year" Dollars. Total costs per year are divided between site costs and program costs. Site costs include: personnel; electrical power; leases; maintenance of structures and other site installations; road maintenance and winter access program; transportation; spares and repair parts; and, other technical operating costs and miscellaneous costs not otherwise covered. Program-related costs include: system modernization; radome replenishment; training; second-level engineering; pedestal overhaul; fuel tank replacement and contamination cleanup; and, engine generators.

Examination of Figure F-1 illustrates that, according to the SEIC study, the number of radars after 1995 is constant at 59 and the year-to-year increase in site costs is approximately constant at about 3 percent per year from 1996 until 2010. In 1996, site costs are estimated at \$41.0M, which equates to approximately \$38.6M in 1994 dollars. Thus, the site costs from 1996 to 2010 are a constant \$38.6M per year in 1994 dollars.

Notice that in the year 2000, program costs of \$6.3M are estimated and these grow at a rate of about 3 percent per year from 2000 to 2010. This equates to approximately \$5.25M dollars per year in 1994 dollars for program-related costs. Also note that from 1989 until the year 1999, program-related costs are large and there are significant fluctuations from year to year. This is attributed to the programs required to modernize and upgrade the older FAA en route radars and to extend their life so that they will survive until 2010 and beyond. Thus, there are two types of program-related costs; those required to modernize radars and extend their useful life; and, those required to support radars over their life cycle. The cost of \$5.25M is in the latter category; i.e., support program costs. Thus, support program costs on a per radar basis are approximately \$89,000 per site.

Consider the average site cost per radar. According to Figure F-1, the annual site costs are \$38.6M for 59 radars, or an average cost per site per year of \$654,000. But, the mix of radars according to the SEIC study was composed of 20 older radars and 39 ARSR-4 radars. Since the ARSR-4 radars are new and nominally unattended sites, one would expect the site costs to be less than that of the older radars. Figure F-2 shows the distribution of site costs among the various cost categories. A quick calculation shows

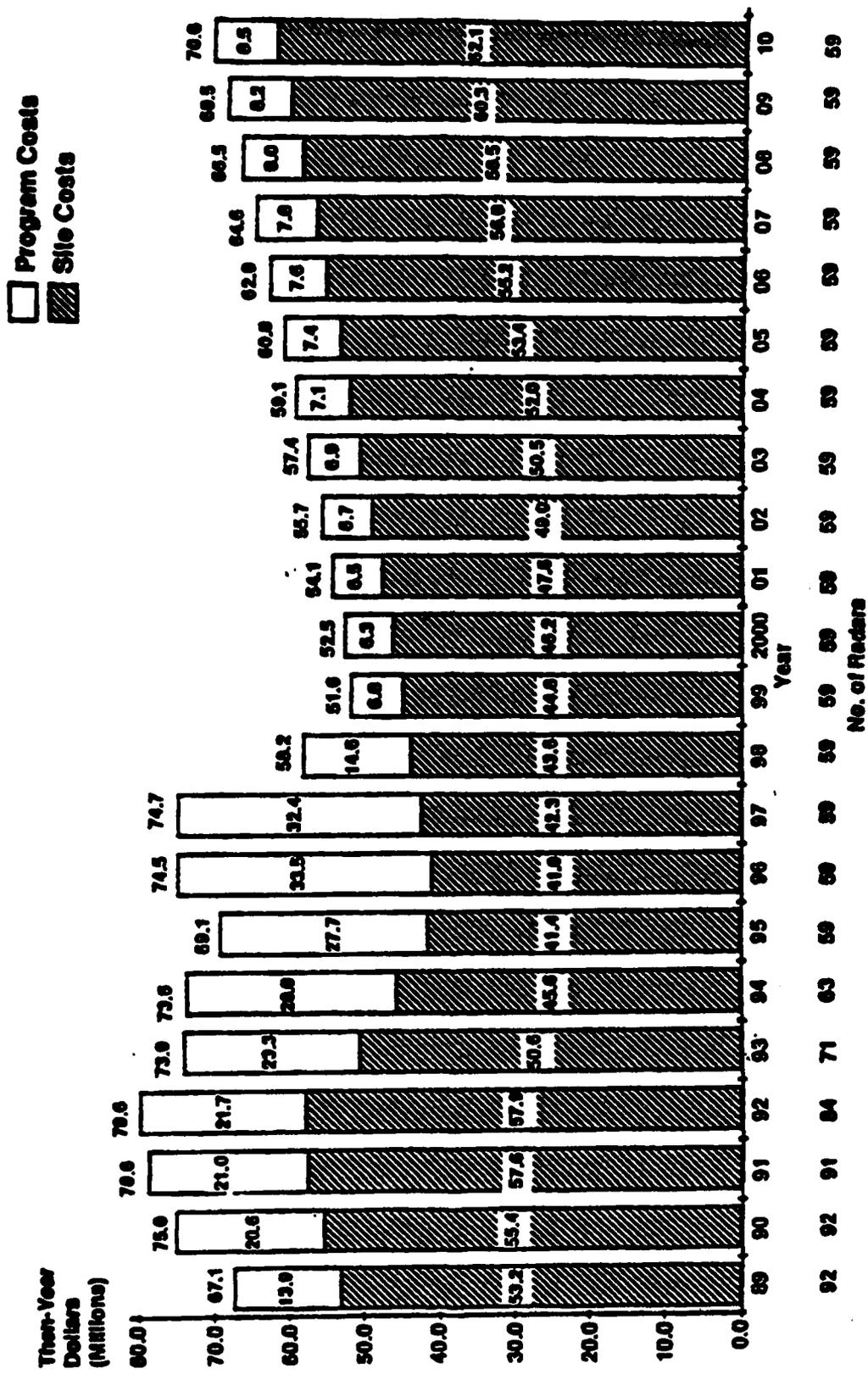


Figure F-1. Overall Operations and Support Costs

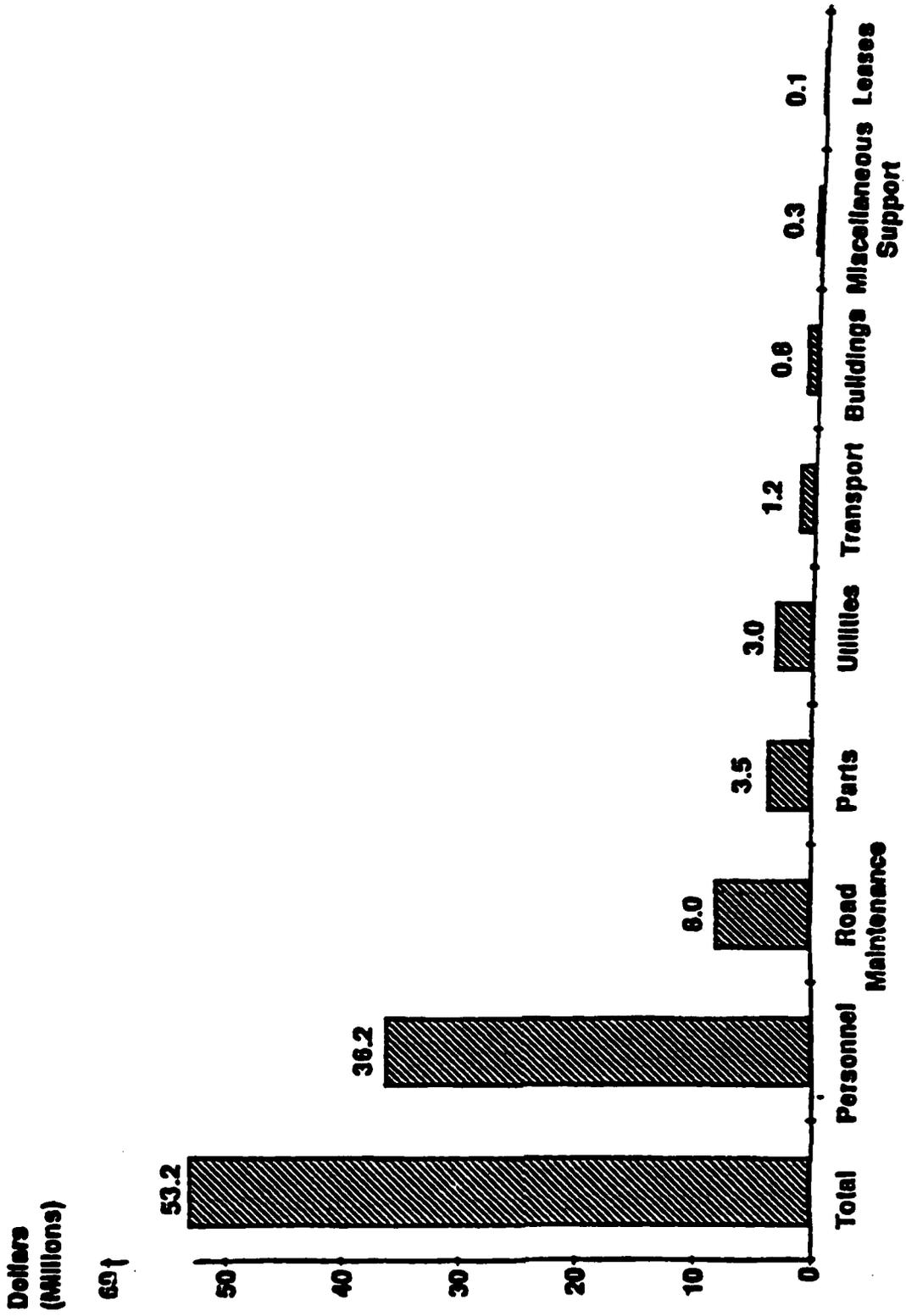


Figure F-2. Long-Range Radar Site-Specific Costs

that about 68 percent of the total site costs is attributable to personnel costs. Further, the study provides estimates of site costs for each radar in each region. Analysis of these site costs yields an average of \$475,000 per radar per year for personnel costs. Thus, the total site cost per radar per year averages approximately \$700,000. This value can be validated directly from Figure F-1 by taking the average per site cost in 1994 dollars for each year from 1989 to 1994. This calculation yields a value of \$705,000 per radar per site for older radars. Using the value of \$700,000 per older radar per year, one can calculate the total site cost of the 20 older radars as \$14.0M and of the 39 ARSR-4 radars as \$24.6M or \$630,000 per new radar per year.

According to the analysis of the present en route radar architecture, there are 116 radars consisting of 69 FAA radars and 47 JSS radars. By the year 2000 there will be 78 operational FAA sites and 65 JSS sites (Appendix H, Part 2). The per annum operations and support costs in 1994 dollars for older radars is \$789,000 and for 78 radars this is approximately \$61.5M per year.

Based on the CIP programs required for modernization and extension of useful life of the older radars, a cost of \$90.5M consisting of the following program estimates has been calculated:

44-39 Sustain/Relocate ARSR	\$5.0M
44-40 LRR Improvements	\$30.1M
44-42 LRR Radome Replacements	\$50.4M
44-43 Radar Pedestal Vibration Analysis	\$5.0M
Total Modernize/Extend Life Costs	\$90.5M

Thus, the costs to the FAA for the 8-year period from 1994 to 2002 is estimated to be:

$$90.5M + (\$61.5M \times 8) = \$582.5M$$

Next, consider the JSS costs. Presently, the JSS system consists of 47 older radars and by 1997, 31 will be replaced by ARSR-4s in CONUS and 1 site will be added in Caribou, ME, and 2 more in Pacific, (HI); six in CONUS and two others, (one in HI and one in AK) will remain unchanged, plus six dislocated sites left by ARSR-4. Thus, 40 ARSR-4 radars plus eight older radars will be in place in 1997, including 17 FPS-117 in AK, which together will constitute the 65 JSS radar complement. Costs for these sites are calculated as follows:

33* older radars from 1994 to 1997 (33 x 789,000 x 3) =	\$78.1M
40 ARSR-4 radars from 1997 to 2002 (40 x 719,000 x 5) =	\$143.8M
8** older radars from 1994 to 2002 (8 x 789,000 x 8) =	\$50.5M
Total JSS costs for 8 years:	\$272.4M

* CONUS-31, Mt Kaala-1, Mt Santa Rosa-1 radar to be replaced by ARSR-4.

** These are the sites to remain with existing radars.

17 AN/FPS-117 from 1994 to 2002 (17x719,000x8) = \$97.8M

Thus, the total cost to extend life, operate, and support the en route radar system consisting of FAA and JSS radars is estimated at \$952.7M.

The costs associated with the deactivation decision can now be estimated. Consider that there are two types of costs associated with deactivation. The first type of cost is one that directly results from the deactivation decision (e.g., disestablishment and clean-up of the 78 LRR sites) while the second type of cost is related to, but not a direct result of, the decision (e.g., 25 first buy Mode S for en route). Table F-1 has been constructed to provide an evaluation of the total costs associated with the deactivation decision in both categories and, while the total costs are in excess of \$2.0B, the costs directly related to the decision are approximately \$138.6 million.

Thus, the direct cost of \$138.6M provides the potential savings associated with replacement of approximately \$1.4B resulting in a benefit-to-cost ratio greater than 10.

Table F-1. LRR Deactivation Costs

	LRR Deactivation Costs (in 1994 \$M) for aircraft surveillance (1994 - 2002)	LRR Deactivation Direct Costs	Other En Route Surveillance Costs	Total Costs
1.	Modernize/Extend the life of the LRRs ^{F1}		90.5	90.5
2.	Operate/Support 78 FAA LR Rs ^{F2}	21.6	470.4	492.0
3.	Operate/Support 41 and 40 New JSSs ^{F3}		272.4	272.4
4.	Operate/Support 17 Alaska AN/FPS-117 ^{F3}		97.8	97.8
5.	Procure 25 Mode S sites ^{F4} , 2 Beacon-Only		105.0	105.0
6.	Additional 53 Mode S Beacon-Only sites ^{F5}		222.6	222.6
7.	Disestablish 78 LRRs and Clean-up ^{F6}	117.0		117.0
8.	Surveillance System Enhancements (CIP 34-40) ^{F7}		180.0	180.0
9.	NEXRAD Implementation ^{F8}		510.0	510.0
10.	Additional Aircraft Transponder Costs ^{F9}	Not	estimated	
	TOTALS	138.6	1,948.7	2,087.3

^{F1} Modernization is required to extend the life of the LRRs until deactivation or replacement with ARSR-4. Thus, while costs are related to the deactivation decision, they are not directly attributed to the deactivation decision.

^{F2} If replacement is to be accomplished by 1998 for all 78 sites, not only for scheduled 40 ARSR-4 sites, the cost would be to operate and support 78 older radars for four years. Thus, the cost if replacement were to occur would be $(4 \times 61.5) + (4 \times 56.1) = \$470.4M$.

^{F3} These costs are required for either option since the collocated beacons are required for ATC purposes.

^{F4} These radars are being procured as part of Mode S first buy and are not directly attributable to the deactivation decision.

^{F5} The LRR deactivation decision requirement is for beacon coverage, not for Mode S coverage, thus, the cost for additional beacons is directly attributable to the LRR decision but the incremental costs for Mode S are considered a related cost item.

^{F6} This is an average cost estimate and includes disposal of radars, conversion to beacon-only site, and site clean-up including removal of hazardous materials

^{F7} This cost is not required because of deactivation decision.

^{F8} This cost is not directly attributable to deactivation since the program was planned before the LRR decision. However, deactivation can not occur without proper implementation of this program.

^{F9} Transponder prices are available in Section 3.2.3 but the costs for fleet equipage are not included. These would be direct costs resulting from deactivation but would not be costs to the FAA.

APPENDIX G

Mini Descriptions of Related Programs

This appendix provides a brief description of all programs that are related to the Long Range Radar deactivation decision and that are identified in this report. They are presented and discussed below in numerical order according to the CIP program number.

21-03; Direct Access Radar Channel (DARC) System: This program provides backup to the ARTCC host computers and in the event of a failure DARC continues to track and to present full data blocks to the controller. Enhancements include automatic track initiation, mosaicing, and real time quality control. The value of DARC is that it eliminates the use of mechanical target markers and the need to move the PVD to the horizontal position in the event of computer failure. This program should be examined to determine if there is any need for software modifications based on the deactivation of primary radar inputs and the elimination of the capability to reinforce beacon target tracks.

21-06; Traffic Management System: The TMS functions include: Central Altitude Reservation Service (CARF), Airport Reservation Service (ARF) Central Flow Weather Service Unit (CFWSU); and, various flow management programs with integrated En Route Metering (ERM) functions including Departure Sequencing Program (DSP), En Route Spacing Program (ESP), and Arrival Sequencing Program (ASP). The replacement of the ARSR weather with NEXRAD products must be examined to determine the impact on the TMS software, interfaces, and planning algorithms. NEXRAD products could also enhance the TMS planning capabilities.

21-12; Advanced Automation System: The AAS program provides a new automation system that includes improved controller work stations, computer software with additional functionality, and new processors. This is accomplished in five steps: PAMRI; ISSS; TAAS; TCCC; and, ACCC. Because of the deactivation of the LRRs, software changes may be required in the ISSS and ACCC to accommodate the loss of primary target inputs used for tracking and reinforcement as well as the replacement of ARSR weather with the NEXRAD products. For example, the WARP program has been invented in part to accommodate the need to display NEXRAD products on the Common Console of ISSS prior to the implementation of the ACCC.

21-15; Area Control Facilities (ACF): This project is intended to establish 23 Area Control Facilities to replace the ARTCCs. Phase I, the pre-commissioning phase, is intended to establish the ACF and includes airspace design, equipment upgrades, software modifications, and routing of surveillance and communication data to support facility backup. Phase II relocates TRACONS and necessary remoting of radar interfaces and communications. Changes to the radar system including beacon relocations, beacon range extension, and elimination of en route primary radar must be accounted for in the design of the ACF as well as the new Metroplex Control Facility (MCF) project.

23-01; Flight Service Automation System (FSAS): This project improves pilot access to weather information and NOTAMs, simplifies flight plan filing, and provides a flight service

automation system that can handle projected increases in demand for flight services without proportional increases in staff. Modifications to FSS hardware and software may be required to accommodate the new weather products from NEXRAD and the loss of the ARSR weather products.

23-02; Central Weather Processor (CWP): As described in the CIP, this project improves the collection, synthesis, and dissemination of weather information throughout the NAS to pilots, controllers, traffic management specialists/coordinators, and meteorologists. This project provides the Center Weather Service Unit/Central Flow Weather Service Unit (CWSU/CFWSU) meteorologists with automated workstations which greatly enhance their ability to analyze rapidly changing, potentially hazardous weather conditions, and ensures that the latest and best information is provided to all system users. It also provides for a mosaic display of multiple weather radars. These improvements are deemed necessary to reduce accidents and air traffic delays directly related to weather. It includes the MWP and the RWP processors and functions.

Recently, the RWP and the MWP have been combined into the Weather and Radar Processor (WARP) partially in order to accommodate the deactivation of the LRRs and the replacement of the weather products with NEXRAD products in the ISSS. A major decision affecting this program consists of the future use of the ARSR-4 weather products. If not accounted for in the WARP, they will not be able to be easily used in ISSS and ACCC.

23-05; Aeronautical Data Link (ADL): This project will develop a digital telecommunications system to provide a variety of weather and ATC data link services. Weather products such as surface observations, terminal forecasts, winds aloft forecasts, pilot reports, and hazardous weather advisories will be provided to pilots on a request/reply basis. Specific definition of ATC data link applications will result from an associated R&D effort. The availability of data link communications will improve air/ground communications and contribute to system safety and capacity by enhancing pilot accessibility to information, relieving congested voice frequencies, and reducing the workload of pilots, specialists, and controllers. The Data Link Processor will be used to accomplish the connectivity between the WARP/ISSS and the Mode S Data Link/Pilot. This project will be positively affected by the deactivation of the LRRs since this will accelerate the availability of NEXRAD products and Mode S. An issue with respect to the availability of Mode S ground stations for transmission of the weather information to the pilot needs to be addressed since the beacon coverage may be a combination of Mode S and ATCRBS.

23-09; Automated Weather Observation Service (AWOS): AWOS obtains aviation-critical weather data (e.g., wind velocity, temperature, dew point, altimeter setting, cloud height, visibility, precipitation type, occurrence, and accumulation) through the use of automated sensors. It will process the data, and allow dissemination to pilots via computer-synthesized voice. Systems located within an ACF area will be connected to the AWOS Data Acquisition System (ADAS). The ADAS will collect and concentrate weather messages from AWOSs and the National Weather Service (NWS) Automated Surface Observing Systems (ASOSs) for internal distribution within the ACF and national distribution via the WMSC Replacement to the NWS. This configuration will support the closing of the National Communications Center and will make weather observation data available to pilots on a timely basis for safety and efficiency. The LRR

deactivation is not expected to have any impact on the AWOS program except that the WARP will be required to interface with the ADAS.

24-12; Mode S: This project will improve the surveillance capability of the Air Traffic Control Radar Beacon System (ATCRBS). Mode S provides more accurate positional information and minimizes interference. This is accomplished by discrete interrogation of each aircraft and improved processing of aircraft replies. In addition, Mode S provides the medium for a digital data link which will be used to exchange information between aircraft and various ATC functions and weather databases. One hundred and thirty seven (137) Mode S systems will be procured to provide coverage down to the ground at 108 terminals and down to 12,500 feet above mean sea level (MSL) in other areas. Mode S systems are designed to be unmanned at the site and remote maintenance monitored. Existing ATCRBS antennas not already capable of improved azimuth resolution will be replaced and additional antennas procured where increased data rates are required. The critical impact on this program is the decision for the second buy of Mode S sensors that is required to obtain Mode S coverage to 6000 feet. If a negative decision is made, some other means of achieving 6000-foot beacon coverage must be funded (e.g., ATCBI-5 stand-alone beacon systems).

24-15; Long Range Radar (LRR) Program: This project will provide a national surveillance network by installing the ARSR-4 at both existing and new sites and by replacing or upgrading existing radars that are obsolete or require excessive maintenance. Accurate and timely data on the presence and movements of aircraft must be continuously available to the en route ATC system so that maximum use of the airspace can be safely afforded to all users. This replacement/upgrade program will significantly reduce maintenance workload and logistics costs, as well as resolve support problems relating to the non-availability of spare parts for the existing old radars. Included in this program are 42 ARSR-4s, 10 ARSR-3 leapfrog locations, LRR relocations as required and 76 upgraded en route tube-type radars. This program should be modified to provide a modern JSS radar system and to extend the life of the older LRRs until deactivation can take place.

24-16; Weather Radar Program (NEXRAD): This project establishes a weather radar network that will provide accurate aviation weather products. It will also furnish software algorithms to take advantage of the improved radar detection of weather data. This program consists of the definition, development, procurement, and installation of a new Doppler weather radar for en route applications. Interim display capability will be provided by Principal User Processors (PUP) to support operation prior to weather and radar processor (WARP) availability. Several issues concerning LRR deactivation are related to NEXRAD and include: data latency (6-minute scan); ISSS interface; RMMS and availability; 6000-foot coverage; and, radar locations to achieve adequate coverage for ATC application since current site plans result in coverage that is inferior to the existing LRR system.

25-03; RML Replacement and Expansion: The FAA Radar Microwave Link (RML) system provided broadband radar, voice frequency, and data communications between ARTCCs and ARSR facilities, but it is outdated and expensive to maintain. To increase its reliability and to maximize the cost-effectiveness, message quality, and availability of an RML replacement for the

interfacility voice and data transmission needed now and in the future, an integrated transmission system is being implemented. This project must be examined in detail to determine the cost-effectiveness of providing the planned capabilities given the decision to deactivate the LRRs and not to use the JSS sites for ATC applications.

26-01; Remote Maintenance Monitoring System (RMMS): This program provides a system to automate FAA maintenance operations. It provides monitoring and control equipment for most FAA facilities so that equipment performance monitoring, control, and certification can be accomplished from centralized work centers. RMM will permit staffing reductions and consolidation, improve quality of workplace, improve work force utilization, and increase work force productivity. When fully implemented, remote maintenance monitoring permits substantial savings in operating cost and manpower. The major impacts on this program caused by the deactivation decision are removal of all software and interfaces associated with the LRRs. Care must, however, be taken with respect to the JSS radars since the FAA may be required to continue maintenance and RMM capabilities. In addition, software to accommodate the NEXRAD monitoring requirements must be added to the system.

26-04; Maintenance Control Center (MCC): This project provides an MCC in two types of facilities: in General NAS Airway Facilities Sectors (GNAS), known as the GMCC; and in each Air Route Traffic Control Center (ARTCC), known as AMCC. The MCC is the nerve center for monitoring and control of facilities in a specific jurisdictional area. Should facility failures occur, MCC initiates corrective action and notifies the work force by telephone or by the regional FM communication network (an integral part of NARACS). MCCs also serve as centers for communications and coordination during emergency situations (natural/defense/ accident) as well as the primary interface between ATC operations and maintenance/support activities. Modifications to accommodate the LRR deactivation, the new JSS system, and the NEXRAD monitoring requirements must be made in this program.

26-07; Power Systems: This project provides the optimum type and quality of electrical power necessary to ensure high facility availability and reliability, and to reduce operating costs and energy consumption of standby power systems at all major manned and unmanned facilities. Many (approximately 1000) large engine generators will be modified, refurbished, or replaced as required to maintain availability and quality of standby power service. Approximately 120 line-conditioning devices (battery systems/power filters/motor-generators/uninterruptible power systems/etc.) will be provided, where required, to compensate for poor quality or reliability of available utility services. Approximately 1000 facility electrical systems will be modernized as required to support new solid-state electronic systems. This modernization encompasses upgrading facility lightning protection and grounding, bonding, and shielding systems, replacement of obsolete wiring and electrical devices to meet current national electrical code requirements. Electrical system improvements will also be made when required to provide optimum electromagnetic compatibility (EMC) between electronic subsystems and adequate immunity to electrostatic discharges. Approximately 50 percent of these facility electrical system modernizations will be required at large-scale facilities such as ARTCCs, ATCTs, ARSRs, and ASRs. This program must be examined to determine the potential savings associated with

deactivation of the LRR sites and accommodate the new requirements imposed by the stand-alone beacon network, NEXRAD, and the new JSS radar network.

26-08; Modernize and Improve FAA Buildings and Equipment: The large number of buildings approaching the end of their normal service life (generally 20 to 30 years) has created a need for a national program. It is quite probable that it will be more economical to replace some older buildings than to modernize them. Modifications to reparable facilities are being made to keep the buildings in a usable condition through the year 2000. Modifications include improvements to the buildings' weather tightness, installation of cost-beneficial insulation, and other energy conservation upgrades. Old LRR facilities should be examined to extend their life until 2002. Requirements for new stand-alone beacon facilities must be established.

26-17; System Support Laboratory: This project provides facilities and equipment at the FAATC in direct support of CIP projects. Systems are integrated into the laboratory for direct field support; for development and testing of hardware, software, and firmware modifications; and for development of system enhancements. Systems in this laboratory are configuration-controlled and baselined to the level of operational field systems. Modifications are installed, tested, and baselined prior to installation at field facilities. This provides a centralized maintenance and field support capability for deployed systems. All changes to the JSS, beacon, weather, RMMS and other systems caused by LRR deactivation must be integrated into the SSL.

34-12; ATCBI Establishment: ATC surveillance of aircraft by ground-based equipment will be required well into the next century. This project will establish surveillance capability at new qualifying ATC facilities. Ground-based ATCBI surveillance units will be procured to support new establishments through existing contracts (quantity and locations to be determined). This program must be implemented to satisfy the 6000-foot beacon coverage requirement if a negative decision on the Mode S second buy is reached. If a positive Mode S second buy decision is reached, this program may be terminated.

34-20; Surveillance System Enhancements: This project improves surveillance system capability through two related enhancements that collectively improve radar accuracy for target positioning, conflict alert, and minimum safe altitude warning (MSAW); reduce track-swapping; and allow full use of the Mode S discrete addressing capability. The first enhancement, the Integrated Radar Beacon Tracker (IRBT), will be developed and installed at those locations equipped with both primary and Mode S secondary radars. The IRBT will simultaneously correlate Mode S and primary reports at the radar site into a single track report, thus reducing the processing time required later at the ATC facility and improving the accuracy of the reported aircraft position. The Mode S, ASR-9, and ARSR-4 will incorporate the capability to operate with IRBT information. ARSR-3 radars may be provided with the capability to interface with Mode S units. This project should be re-examined to determine its need given the LRR deactivation decision. Correlation at the sensor is not necessary and is presently being accomplished at the ARTS and ARTCC. Termination of this program could represent a substantial savings to the FAA if it is determined that it is not needed or that it can be substantially reduced as a result of LRR deactivation. It can further be argued technically that all surveillance data should be provided to the center or terminal facility and not correlate and combine tracks at a

radar site from different sensors. This approach would take advantage of surveillance data fusion technology. This is an important consideration in particular with the advent of the ADS information.

41-21; En Route Software Development Support: Support is required for the integration and implementation of NAS en route software changes to correct operational problems and provide systems enhancement. The project will develop software functions and provide support services to implement and maintain en route software as per the following tasks: Support for NAS en route system releases; FAATC support; Project requirements analysis; Three-level weather; Flight Plan Communications Link (FPCL); and, San Juan FDIO. All software changes to the en route system required by the elimination of primary radar and increased beacon data rates must be considered as part of this effort. In addition, the plans for three-level weather should be re-examined as a result of the decision not to use ARSR-4 weather and to wait for the interface of the NEXRAD with the ISSS in such a fashion as to bypass the host computer software.

43-04; Flight Service Automation System (FSAS) Computer Replacement: The objective of this project is to establish the requirements and provide the procurement methodology for replacement of current flight service automation system equipment. This includes identification and evaluation of alternatives to automated weather processors (AWPs), flight service data processing systems (FSDPSs), and the automated flight service station (AFSS) consoles. Funding is required to procure or lease the replacement systems by the end of the supportable life cycle of the model 1 full capacity equipment. This project will identify new requirements or alternative solutions to the current system, and develop the specification for the replacement of the AFSS system equipment. This project will continue the operation of the 61 AFSSs with upgraded automation hardware, software, procedures, supply support, and training. Software development for the FSAS computer replacement must accommodate the changes in the weather inputs resulting from the transition to NEXRAD products and the implementation of the ISSS interface.

44-39; Air Route Surveillance Radar (ARSR) Sustain/Relocate: The purpose of this project is to relocate existing long-range radars as required to enhance and improve air space coverage to meet air traffic requirements. The regional requirements will be prioritized and validated at FAA Headquarters. The relocation projects will be coordinated to ensure compatibility with the ARSR-4 leapfrog program and the Joint Radar Planning Group recommendations for ARSR-4 relocations. The refurbishment or retrofit of FPS-60 radars will be accomplished in a manner which provides logistics support and remote maintenance monitoring capabilities. The availability of additional radars will improve coverage by adding sites and by providing spares needed to perform site relocations. Approximately two sites per year will be relocated, according to national air traffic requirements. This project must be totally re-examined based on the decision to deactivate the LRRs. Relocations may no longer be required but sustainment of the LRRs until 2002 is a firm requirement and must be accomplished in order to effect an orderly transition to a beacon-only capability.

44-40; Long Range Radar (LRR) Program Improvements: This project will provide improvements to the current inventory of long range radars to help extend their useful life for up to 15 additional years. Improvements will continue to be made to the current older generation of

long range radars to ensure their continued satisfactory performance beyond the year 2000. A replacement radar set control will be installed in the ARSR-1/-2 radars. Cable trays will be purged of unused cables. Facility grounding will be brought up to current FAA standards. This project is critical to the deactivation decision since an orderly and well-planned transition to the beacon-only capability depends on extending the life of the LRRs until at least 2002.

44-42; Long Range Radar (LRR) Radome Replacement: The objective of this project is to replace existing radomes at all Long Range Radar (LRR) facilities currently in the NAS. The majority of the radomes at LRR sites have been in service for 25 to 30 years. These radomes have exceeded their normal life expectancy and their maintenance has become labor intensive. Current radomes are also not compatible with the new Mode S monopulse antenna system. These radomes are too small to physically accommodate the Mode S antenna system. In addition, radar signal interference, such as antenna beam skewing and excessive attenuation, will be minimized as compared to existing radome metal frames and dielectric materials. The approach is to replace all obsolete and Mode S-incompatible LRR radomes. Radome procurement will be initiated with a Request For Proposals (RFP). The technical specification will require that the new radome be compatible with the Mode S system. This project should be critically examined to determine the necessity for new radomes given the deactivation decision. Clearly the radomes must last at least until 2002 at which time a beacon-only radome may be required for some but not all sites.

44-43; Radar Pedestal Vibration Analysis: This project will provide vibration monitoring sensors on radar pedestals and vibration analysis equipment to analyze the monitored data. Radar pedestal equipment maintenance is an expensive and labor-intensive activity. There is currently no reliable method of predicting impending failures or monitoring the physical and functional integrity of radar pedestals. The FAA operates a scheduled seven-year overhaul cycle requiring 15 to 18 scheduled overhauls annually. An additional eight to ten emergency pedestal repairs are also performed each year. Vibration sensors will be installed on radar pedestals, initially on en route radar pedestals. Vibration analysis equipment will be located at the FAA Logistics Center and selected maintenance centers. Monitoring and analysis will be performed to provide information on impending pedestal problems to eliminate unnecessary overhauls, reduce emergency repair actions, and more accurately budget resources for pedestal maintenance. Remote maintenance monitoring capability at radar facilities will be analyzed to determine compatibility with pedestal vibration monitoring. This project should be examined to evaluate the need based on the deactivation decision. If for example, the existing LRR pedestals will be used in beacon-only operation and the primary antenna is not removed, then this project is essential to even the beacon-only system.

44-45; ATCBI Relocation: The purpose of this project is to provide continued support for the FAA's ATCRB/ATCBI systems. The project provides relocation of the newer ATCBI systems replaced by Mode S or the "front-end" systems provided by an option in the ASR-9 project to sites which presently use the older vacuum tube-type (ATCBI-3s) as well as provide for Radar Beacon Performance Monitors (RBPMs) at 25-30 ATCBI locations where shortages exist. Additionally, this project provides for any immediate or emergency requirements for ATCBI. The approach consists primarily of technical and engineering services performing "in-place" installation at ATCBI- 3 locations. Services will also be performed at sites receiving Mode S or front end

systems to prepare and ship assets. Relocated Remote System Monitors (RSMs) will be used for new establishments at locations presently without an RSM. At the completion of the ongoing Mode S procurement, the following systems will have been made available for relocation or re-establishment of new ATCBIs/ATCRBs: 52 ATCBI-5s; 44 ATCBI-4s; and, 96 RBPMs. Additional hardware will be needed to support the relocation effort for beacon test sets, line drivers, and site spares. Modification to this program will be required based on the decision for the Mode S second buy, the deactivation of the LRRs, and the need for relocations based on the requirement for 6000-foot coverage.

44-46; ATCBI Replacement: Ground-based surveillance of aircraft for air traffic control will be required well into the next century. This project will replace aging and obsolete ATCBI equipment with Mode S and compatible systems to maintain ground surveillance, increase supportability, and establish an air/ground data link. The existing ground-based ATCBI surveillance systems will be replaced with Mode S or compatible beacon systems. Data link services are integral to Mode S, and alternate systems are being considered where Mode S coverage is not provided. A contract is in place for 137 Mode S systems; a procurement of 259 more beacon systems is planned. A detailed analysis of costs, benefits, alternatives, and tradeoffs is being conducted to determine the optimal type of beacon and data link systems to be procured. To satisfy new requirements for beacon systems, an interim procurement of beacon systems is planned prior to the planned 259-system purchase. Depending upon the type of system procured, there may be a reduction in the number of systems required in the second procurement. There is a requirement to purchase replacements for the existing ATCBI beacons and systems for newly qualified sites. There is also a requirement to provide data link services to the NAS. Based on the decision to deactivate the LRRs and the need for 6000-foot coverage, this project may need to be modified or accelerated in order to satisfy these new requirements.

44-48; AN/FPS-117 Beacon Improvements: This project will provide improved beacon radar performance from the U.S. Air Force AN/FPS-117 Minimally Attended Radar (MAR) systems in Alaska. The improvements are needed to allow use of standard air traffic control separation standards within the airspace covered by the FPS-117 beacon radar subsystem. This project is critically important because the FAA relies on coverage from these Air Force radar sites for the majority of Alaskan airspace. Further international air route structure changes are expected to greatly increase commercial traffic in the airspace covered by the FPS-117 sites in the early 1990's. 18 AN/FPS-117 modifications are required. Because the FPS-117 radars are owned and maintained by the Air Force, the responsibility for modification of those radars shall remain with the Air Force. That service will procure and install the modification using FAA funds provided on an interagency agreement. This project has increased importance resulting from the LRR deactivation decision since the AN/FPS-117 beacons are required to achieve the coverage needed for ATC applications in Alaska.

46-01; Remote Maintenance Monitoring System (RMMS), Sustain: This project will expand the existing RMMS network, replace obsolete COTS components, and enhance/upgrade existing maintenance automation software. The modernization will sustain work force productivity achieved through the implementation of RMMS capability, and will maintain system currency with technology. Maintenance concepts and functional system specifications will be upgraded to

enhance the RMMS implemented prior to 1992 under projects 26-01 RMMS and 26-04 MCC. Replacement hardware and software will be procured as required to meet the new specifications for system upgrades, and re-hosting of software will be considered where appropriate. The modernization of the RMMS will provide for the replacement or enhancement/upgrade of the Maintenance Processor Subsystem (MPS) and its related peripheral equipment, application software, and interfaces with both the Area Control Facility (ACF), Maintenance Control Center Processor (MCCP), and the General NAS Sector Maintenance Control Center (GMCC). Accommodation of the new requirements resulting from the deactivation of the LRRs and the dependence of the system on NEXRAD weather must be factored into the RMMS system.

46-04; Maintenance Control Center (MCC) Enhancement: This project will enhance/upgrade the MCCs in each Airway Facilities Sector. It will provide back-up power to sustain sector MCC operation during extended power outages. The MCC serves as the focus for facility maintenance and restorative activities within a specific jurisdiction. The final configuration will be the result of an evolutionary process incorporating new equipment additions to the NAS and maturing operational requirements. Aging Commercial-Off-The-Shelf (COTS) components of the MCC hardware and software systems will be replaced, enhanced, or upgraded. The modernization will sustain work force productivity achieved through the implementation of RMMS capability, and will maintain system currency with technology. Systems implemented by this project will use capabilities provided by the remote maintenance monitoring system and will require interfaces and coordination with all project activities implementing RMM capabilities. Accommodation of the new requirements resulting from the deactivation of the LRRs and the dependence of the system on NEXRAD weather must be factored into the RMMS system.

46-08; Modernize and Improve FAA Buildings and Equipment Sustained Support: This project is a continuation of project 26-08 Modernize and Improve FAA Buildings and Equipment. New standard facility designs were developed under project 26-08 for upgrading or for the replacement of buildings and plant equipment which house and support NAS navigation, communications, surveillance, and visual/electronics landing systems. Seismic studies are conducted under project 26-16 at FAA facilities in high risk areas. While these facilities were built to applicable standards of the time, many do not meet current standards. These facilities will be modified to bring them into compliance with the latest standards. The approach is to continue the comprehensive modernization and improvement of buildings and plant equipment which house and support NAS facilities. Modifications to reparable facilities will be made to keep the buildings in usable condition. Modifications will also be made to maintain the buildings' integrity, enhance energy conservation through the installation of cost-beneficial insulation, and to meet new equipment environmental support requirements and structural seismic compliance. Buildings and structures which cannot be economically upgraded or modified will be replaced with modular structures based on standard national designs. This project will cover all buildings and structures currently used to house, support, and maintain NAS facilities and systems. The plans for modernization of facilities associated with the aging ARSR radars must be re-examined since the facilities upgrades may no longer be required as a result of the decision to deactivate the LRRs.

56-17; System Support Laboratory Sustained Support: This project provides facilities and equipment at the FAA Technical Center (FAATC) for testing, evaluation, and integration of new

systems. To support the FAA test and evaluation policy, the System Support Laboratory will duplicate future systems, equipment, and interfaces necessary to establish realistic environments for all types of developmental, operational, and production acceptance testing. The testing will ensure that total system requirements are met prior to installation at field facilities. Upon completion of testing, systems will be integrated into the laboratory for direct field support, development and testing of hardware, software, and firmware modifications, and development of system enhancements. Upgrades and modifications to the laboratory to reflect the new en route surveillance system architecture and beacon-only capability must be factored into this project.

56-29; On-site Simulation-Based Training Systems: This project provides for the development of a number of stand-alone, simulation-based training systems for the training of technical employees. Simulation-based training devices provide for a safe, efficient, and flexible training environment. The training systems to be developed will provide initial training for Air Traffic and Airway Facilities personnel in a realistic environment without taking operating equipment out of service, risking injury to personnel, or damaging the system. The FAA is improving its training programs through the use of simulation technology. Over the next decade, future training needs for complex automated systems are being identified to have simulation training available before the delivery of the operational equipment. High-fidelity simulations are planned for selected FAA sites which have large Air Traffic and Airway Facilities student populations. Simulations technology will be used to prepare students to meet the challenges of the job environment without risk to personnel or systems. In the en route system, the feasibility of several approaches to stand-alone radar training systems, through studies or prototyping of systems with capabilities of freeze and playback of scenarios, and the needed training improvements will be determined. These radar training systems must be able to interface with Planned View Displays (PVDs) and common consoles. This capability will enable several facilities to have their controller work force ready to change over to the Initial Sector Suite System (ISSS). Additionally, it will provide PVDs for use either in the operational environment or to train additional employees. The system will operate through the ISSS and provide a base for additions when needed for ACCC. This project is directly affected by the transition to NEXRAD weather products, the deactivation of the en route LRRs, and the resulting changes to the training requirements and must be integrated into the training and simulation program plans.

56-41; Radar Analysis Tool: This project optimizes radar operational performance by providing a tool for automated analysis. While some capability exists today, integration/evaluation/current capabilities are dispersed throughout many incompatible packages, and with the advent of such systems as the ARSR-4 and ASR-9, new requirements exist for capabilities not contained in any existing package. The Generic Tool for the Analysis of Radars and the Evaluation of Systems (GENTARES) will provide a single, integrated tool for analyses of all FAA radar systems. Initially a single, integrated software package consisting of a consolidation of all functions currently available in the dispersed radar analysis packages/systems will be developed. Also included will be support capabilities for the ARSR-4 and ASR-9 radar systems. While the ARSR-4 will be part of the JSS system and the ASR-9s are unaffected by the LRR deactivation decision, it is recommended that this project be examined to revalidate the need since the ARSR's will not be used for ATC applications.

56-53; Refurbish AN/FPS-20 Radars: This project will provide for the removal and refurbishment of surplus military AN/FPS-20 series long-range surveillance radars for subsequent use by the FAA. Decommissioned AN/FPS-20 radars which have been declared surplus by the U.S. Air Force and made available to the FAA will be removed and sent to the FAA Logistics Center for refurbishment. This project may be required to sustain the LRRs until 2002 but if not, it may be a candidate for cancellation based on the LRR deactivation decision.

61-22; Automatic Dependent Surveillance (ADS): Implement a satellite-based ATC surveillance and communications service to aircraft in oceanic environments in coordination with international ATC authorities based on GPS-derived position reports to ARTCC derived onboard the aircraft. Benefits include an increase in safety and efficiency of flight operations. Oceanic ATC operations are conducted manually, with controllers monitoring aircraft flight progress based on HF voice position reports from flight crews. Aircraft must adhere to rigid route structures, and relatively large separations must be maintained to accommodate untimely position reports and the lack of a two-way pilot/controller data link. The resulting airspace capacity limitations and the inability of controllers to approve flight plan changes force aircraft to operate on less efficient routes. Similar problems exist for offshore, low-altitude domestic airspace, and other non-radar environments.

The satellite-based ADS system will permit tactical and strategic control of aircraft. Automated position report processing and analysis will result in a precise monitoring of aircraft movement. Automatic flight plan deviation alerts and conflict probes will support increased safety, reductions in separation minima, and increased accommodation of user-preferred routes and trajectories. Graphic display of aircraft movement and automated processing of data messages, flight plans, and weather data will significantly improve the ability of the controller to manage oceanic air traffic. Extension of this program to provide backup to the en route beacon-only surveillance system in the event of beacon radar or aircraft transponder failure should be examined.

63-02; Central Weather Processor (CWP) Interfaces: Develop, test, and evaluate required CWP interfaces to other elements of the NAS to realize the full potential of CWP to disseminate real-time weather information to pilots, air traffic controllers, and traffic management specialists. This project is being completely redefined based on the decision to integrate the RWP and the MWP functions. It is being renamed the Weather and Radar Processor (WARP) program and will accommodate the new NEXRAD/ISSS interface. Other requirements with respect to the AFSS are also expected to be included. The issue of use of ARSR-4 weather inputs however must be resolved before this procurement is awarded since the present plan is not to include ARSR-4 Wx in the system. This program is one of the key programs that pace the evolution to a beacon-only capability.

63-05; Aeronautical Data Link (ADL) Communications and Applications: Develop data link applications for improving air-to-ground data communications services to achieve goals of higher productivity, increased efficiency, enhanced safety, and increased capacity through error-free communications and reduced voice frequency congestion. This effort will support the creation of the future ATC environment and provide the technical development needed to implement the enhanced DLP, Aeronautical Telecommunications Network (ATN), and Mode S

data link system as an air-to-ground data communications element within the NAS. This project could be affected by decisions relative to LRR deactivation. For example, if a decision is made to use ATCRBS rather than Mode S to achieve 6000-foot beacon coverage, Mode S services may be limited to 12,500 feet and above.

63-20; Weather Enhancements: Improve the weather short range forecasting and nowcasting for aviation. This program will improve hazardous weather warnings and short range forecasts affecting the safety, efficiency, and capacity of the NAS. New techniques will be developed for the use of single sensors, such as NEXRAD and TDWR, and multiple sensors to detect and predict changing weather conditions. Activities in this project consist of new algorithms including turbulence, gust fronts, and convective initiation; algorithms, numerical weather prediction models and/or expert systems to predict changes in ceiling and visibility; and methods of detecting and predicting clear air turbulence, icing, and upper winds. If a decision is made to attempt to overcome the NEXRAD data latency issue, this project may be expanded to include NEXRAD enhancements such as improved scanning strategies and weather reflectivity tracking techniques and other alternatives.

63-22; Aviation Weather Products Generator (AWPG): This project will integrate all NWS/FAA weather sensor data into real-time weather products for use by the aviation community. As a result of the efforts of the NWS and the FAA, weather system detection and data processing capabilities are being dramatically improved. The acquisition of sensor systems like NEXRAD, wind profiler, and next generation geostationary operational environmental satellite by the NWS, and terminal area weather sensors like TDWR will allow the acquisition of high-density, state-of-the-atmosphere data. The NWS and the FAA will jointly develop the aviation weather forecasting techniques necessary to convert these data sets into high-resolution aviation weather forecasts. These forecasts will be generated by NWS Aviation Weather Interactive Processing Systems (AWIPS) at their Warning and Forecast Offices (WFOs). The AWPG will store these forecasts into a gridded database, merge and smooth the data sets into regional and national data sets, generate aviation user-specific graphic and alphanumeric weather forecast products, and generate voice aviation messages.

The resolution of these problems will be accomplished by providing facilities to receive and process AWIPS-derived products into the NAS. AWPG is divided into two components: a National Aviation Weather Products Generator (NAWPG), and a Regional Aviation Weather Products Generator (RAWPG). Development of the AWPG will be supported by an Aviation Weather Development Laboratory (AWDL). The AWPG will ensure the appropriate integration of NWS AWIPS products into the NAS and provide the means for generating additional specialized aviation weather products, including products derived from FAA systems as well as from the NWS.

As aviation weather products are developed by the AWDL, processing functions will be allocated to the appropriate level. It is envisioned that most local product generation responsibility will be allocated to the AWPG. AWPG products will be interfaced regionally with the upgraded RWP/MWP for ACF utilization. Because there are many WFOs in each ACF area, products will require an ACF area merge. WFO and ACF products of interest to the national level will be

forwarded to the NAWPG. In this case, a merge of ACF products to form a national-level product will be carried out by the NAWPG. As a national-level facility, the NAWPG will provide a great deal of direct support to the national traffic management function.

With the creation of the WARP, this program has been modified to consist exclusively of WARP weather product enhancements. It no longer includes hardware and only addresses the development of software for new aviation weather system products. Extensive modification is required.

64-05; Global Positioning System (GPS) Monitors: This project provides a monitor system to enable use of GPS by civil aviation for supplemental en route navigation and non-precision approaches. VOR/DME is the international standard for civil air navigation. Navigation systems that provide service in the NAS in conjunction with VOR/DME are termed supplemental systems. To better prepare the FAA for the future of air navigation, GPS will serve as a supplemental system for civil aviation in addition to its primary role as a U.S. military positioning system. The FAA will monitor GPS satellite signals to be immediately aware of the operational status of the total GPS navigation system. Monitor data will be used to inform pilots and air traffic personnel of the status of GPS. Studies and experiments will be conducted to finalize requirements and verify performance of alternative monitoring techniques. In response to industry concerns, FAA will focus on a "wide-band" technique which can support future enhancements. The potential of non-ground-based (receiver autonomous) techniques are also being investigated. This project may take on increased significance if the decision is made to use ADS/GPS as a backup to the beacon-only en route system resulting from the deactivation of the LRRs.

APPENDIX H

FULL ACCOUNT OF ALL NAS 116 CURRENT and PLANNED LONG-RANGE RADAR SITES BEFORE AND AFTER ARSR-4 DEPLOYMENT¹

PART 1: Current 116 FAA-Listed Long-Range Radar Sites Before ARSR-4 Deployment (Data used in Table 2-1)

43 JSS sites in CONUS
 2 JSS sites in Alaska
 2 JSS sites in Pacific
 69 FAA sites in CONUS

Item No.	Type No.	State	Location	Current Type	Planned Type
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31 JSS Sites Planned for Replacement by the ARSR-4 Long-Range Radar

1	1	CA	CRESCENT CITY	FPS-66A	ARSR-4
2	2	CA	PASO ROBLES	ARSR-1E	ARSR-4
3	3	CA	MILL VALLEY	FPS-66A	ARSR-4
4	4	CA	MT. LAGUNA	ARSR-3	ARSR-4
5	5	FL	PATRICK AFB	FPS-66A	ARSR-4
6	6	FL	CROSS CITY	ARSR-3	ARSR-4
7	7	FL	KEY WEST	FPS-67B	ARSR-4
8	8	FL	RICHMOND	ARSR-1E	ARSR-4
9	9	FL	WHITEHOUSE	ARSR-60	ARSR-4
10	10	FL	TYNALL AFB	FPS-64A	ARSR-4
11	11	FL	FORT LONESOME	ARSR-3	ARSR-4
12	12	LA	LAKE CHARLES	FPS-91A	ARSR-4
13	13	LA	SLIDELL	ARSR-1E	ARSR-4
14	14	MA	NOTH TRURO	FPS-91A	ARSR-4
15	15	ME	BUCKS HARBOR	FPS-66A	ARSR-4
16	16	MI	EMPIRE	ARSR-3	ARSR-4
17	17	MN	NASHWAUK	ARSR-3	ARSR-4
18	18	MT	MALSTROM(GR FALLS)	FPS-65A	ARSR-4
19	19	MT	LAKESIDE	ARSR-3	ARSR-4
20	20	NC	FORT FISHER	FPS-91A	ARSR-4
21	21	ND	FINLEY	ARSR-3	ARSR-4
22	22	ND	WATFORD CITY	FPS-67B	ARSR-4
23	23	NJ	GIBSBORO		ARSR-4
24	24	NY	RIVER HEAD	ARSR-3	ARSR-4

¹ Source of FAA data: Mike Polchert, ANR-800, FAX August 24, 1993. Source of Military data: Copies of Viewgraphs, 6430.2 CHG 34, Attachment 76.

Item No.	Type No.	State	Location	Current Type	Planned Type
25	25	NY	UTICA	ARSR-60	ARSR-4
26	26	OR	SALEM	ARSR-1E	ARSR-4
27	27	SC	JEDBURG	FPS-66A	ARSR-4
28	28	TX	OILTON	FPS-66B	ARSR-4
29	29	VA	OCEANA	FPS-91A	ARSR-4
30	30	WA	MAKAH	FPS-91A	ARSR-4
31	31	WA	MICA PEAK	FPS-67B	ARSR-4

6 JSS That Will Not Be Used as JSS Sites; 7 JSS Will Be Established at New Sites

32	1	CA	SAN PEDRO	ARSR-1E	
33	2	NM	SILVER CITY	ARSR-2	
34	3	TX	EL PASO	ARSR-1E	
35	4	TX	ODESSA	ARSR-1E	
36	5	TX	SONORA	ARSR-3	
37	6	TX	ELLINGTON	ARSR-1E	

6 NAS CONUS JSS Sites to Remain Unchanged

38	1	AZ	PHOENIX	ARSR-1E	
39	2	LA, AL	CITRONELLE, GR. BAY	ARSR-2	
40	3	MI	DETROIT	ARSR-1E	
41	4	NY	DANVILLE	ARSR-1	
42	5	OR	KENO	FPS-67B	
43	6	VA	THE PLAINS	ARSR-3	

4 Other NAS JSS Sites Outside CONUS

44	1	AK	KENAI	ARSR-3	
45	2	AK	MURPHY DOME	FPS-117	
46	3	HI	MT. KAALA	ARSR-3	ARSR-4
47	4	GUAM	MT. SANTA ROSA	FPS-93	ARSR-4

69 FAA Sites: 23 FPS , 18 ARSR-1, 16 ARSR-2, 10 ARSR-3, and 2 ARSR-60

FPS Sites

1	1	AK	KING SALMON	FPS-117	
2	2	NM	ALBUQUERQUE	FPS-66A	
3	3	LA	ALEXANDRIA	FPS-20A	
4	4	TX	AMARILLO	FPS-67	
5	5	NV	FALLON	FPS-66A	

Item No.	Type No.	State	Location	Current Type	Planned Type
6	6	KS	HUTCHINSON	FPS-66	
7	7	PA	OAKDALE	FPS-67	
8	8	NV	LAS VEGAS	FPS-20A	
9	9	VT	ST. ALBANS	FPS-67B	
10	10	NE	OMAHA	FPS-66	
11	11	SD	GETTYSBURG	FPS-67B	
12	12	PR	PICO DEL ESTE	FPS-67A	
13	13	AL	HALYVILLE	FPS-67B	
14	14	PA	BENTON	FPS-67	
15	15	IL	HANNA CITY	FPS-67B	
16	16	AR	RUSSELLVILLE	FPS-64A	
17	17	CA	RED BLUFF	FPS-67D	
18	18	TX	SAN ANTONIO	FPS-66	
19	19	AR	TEXARKANA	FPS-67	
20	20	CA	BORON	FPS-67B	
21	21	MI	COOPERSVILLE	FPS-66A	
22	22	CA	SACRAMENTO	FPS-20	
23	23	OK	OKLAHOMA CITY	FPS-67B	

ARSR-1 Sites

24	1	GA	MARIETTA	ARSR-1E	
25	2	OH	CLEVELAND	ARSR-1E	
26	3	IN	INDIANAPOLIS	ARSR-1E	
27	4	AL	MONTGOMERY	ARSR-1E	
28	5	MN	MINNEAPOLIS	ARSR-1E	
29	6	TN	JOELTON (NASHVILLE)	ARSR-1E	
30	7	CO	PARKER	ARSR-1E	
31	8	NC	BENSON	ARSR-1E	
32	9	NC	MAIDEN (CHARLOTTE)	ARSR-1E	
33	10	IN	LAGRANGE	ARSR-1E	
34	11	NM	MESA RICA	ARSR-1E	
35	12	OH	LONDON	ARSR-1E	
36	13	MS	BYHALLA (MEMPHIS)	ARSR-1E	
37	14	TX	ROGERS	ARSR-1E	
38	15	WA	SEATTLE	ARSR-1E	
39	16	UT	SALT LAKE CITY	ARSR-1E	
40	17	MO	ST. LOUIS	ARSR-1E	
41	18	TX	FT. WORTH	ARSR-1E	

Item No.	Type No.	State	Location	Current Type	Planned Type
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ARSR-2 Sites

42	1	CO	TRINIDAD	ARSR-2	
43	2	NV	BATTLE MOUNTAIN	ARSR-2	
44	3	KS	GARDEN CITY	ARSR-2	
45	4	CO	GRAND JUNCTION	ARSR-2	
46	5	NM	GULLUP(FARMINGTON)	ARSR-2	
47	6	NE	NORTH PLATTE	ARSR-2	
48	7	WY	LUSK	ARSR-2	
49	8	ID	CASCADE (BOISE)	ARSR-2	
50	9	WI	HORICON	ARSR-2	
51	10	MN	TYLOR	ARSR-2	
52	11	KY	LYNCH	ARSR-2	
53	12	WY	LOVELL	ARSR-2	
54	13	ID	ASHTON	ARSR-2	
55	14	WY	ROCK SPRINGS	ARSR-2	
56	15	UT	CEDAR CITY	ARSR-2	
57	16	KS	OSKALOSSA	ARSR-2	

ARSR-3 Sites

58	1	IL	JOLIET	ARSR-3	
59	2	VA	BEDFORD	ARSR-3	
60	3	IA	ARLINGTON	ARSR-3	
61	4	GA	LINCOLNTON	ARSR-3	
62	5	MS	NEWPORT	ARSR-3	
63	6	OR	FOSSIL	ARSR-3	
64	7	AZ	SELIGMAN	ARSR-3	
65	8	VA	BINNS HALL (IVOR)	ARSR-3	
66	9	MO	KIRKSVILLE	ARSR-3	
67	10	PA	CLEARFIELD	ARSR-3	

ARSR-60 Sites

68	1	PA	TREVOSE	ARSR-60	
69	2	MA	CUMMINGTON	ARSR-60	

PART 2: Future Long-Range Radar Sites with Indicated System Changes After ARSR-4 and Mode S First Buy Deployment (Primary Radar Data are Used in Table 2-3):

44 JSS in CONUS

1 Military-Only in CONUS

1 Military-Only in Caribbean

78 FAA Operational Sites (AERO site not Counted)

19 JSS in Alaska (One Beacon-Only)

3 JSS in Pacific

Item No.	Type No.	State	Location	Current Type	Planned Type
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JSS CONUS Deployment (44)

1	1	AZ	AJO	New Site	ARSR-4
2	2	CA	RAINBOW RIDGE	FPS-66A	ARSR-4
3	3	CA	PASO ROBLES	ARSR-1E	ARSR-4
4	4	CA	MILL VALLEY	FPS-66A	ARSR-4
5	5	CA	MT. LAGUNA	ARSR-3	ARSR-4
6	6	FL	MELBOURNE	FPS-66A	ARSR-4
7	7	FL	CROSS CITY	ARSR-3	ARSR-4
8	8	FL	KEY WEST	FPS-67B	ARSR-4
9	9	FL	TAMIANI	ARSR-3(MERS)	ARSR-4
10	10	FL	WHITEHOUSE	ARSR-60	ARSR-4
11	11	FL	TYNDALL AFB	FPS-64A	ARSR-4
12	12	FL	FORT LONESOME	ARSR-3	ARSR-4
13	13	LA	LAKE CHARLES	FPS-91A	ARSR-4
14	14	LA	SLIDELL	ARSR-1E	ARSR-4
15	15	MA	NOTH TRURO	FPS-91A	ARSR-4
16.	16	ME	CARIBOU Area	NEW	ARSR-4
17	17	ME	BUCKS HARBOR	FPS-66A	ARSR-4
18	18	MI	EMPIRE	ARSR-3	ARSR-4
19	19	MN	NASHWAUK	ARSR-3	ARSR-4
20	20	MT	BOOTLEGGER RIDGE	FPS-65A	ARSR-4
21	21	MT	LAKESIDE	ARSR-3	ARSR-4
22	22	NC	FORT FISHER	FPS-91A	ARSR-4
23	23	ND	FINLEY	ARSR-3	ARSR-4
24	24	ND	WATFORD CITY	FPS-67B	ARSR-4
25	25	NJ	GIBBSBORO	Reactivated	ARSR-4
26	26	NM	DEMING	NEW	ARSR-4

Item No.	Type No.	State	Location	Current Type	Planned Type
27	27	NY	RIVER HEAD	ARSR-3	ARSR-4
28	28	NY	UTICA	ARSR-60	ARSR-4
29	29	OR	SALEM	ARSR-1E	ARSR-4
30	30	SC	JEDBURG	FPS-66A	ARSR-4
31	31	TX	EAGLE PEAK	NEW	ARSR-4
32	32	TX	KING MOUNTAIN	NEW	ARSR-4
33	33	TX	MORALES	NEW	ARSR-4
34	34	TX	OILTON	FPS-66B	ARSR-4
35	35	TX	ROCK SPRINGS	NEW	ARSR-4
36	36	VA	OCEANA	FPS-91A	ARSR-4
37	37	WA	MAKAH	FPS-91A	ARSR-4
38	38	WA	MICA PEAK	FPS-67B	ARSR-4

CONUS Existing JSS Sites (6)

39	1	AZ	PHOENIX	ARSR-1E	
40	2	LA, AL	CITRONELLE. GR. BAY	ARSR-2	
41	3	MI	DETROIT	ARSR-1E	
42	4	NY	DANSVILLE	ARSR-1	
43	5	OR	KENO	FPS-67B	Mode S
44	6	VA	THE PLAINS	ARSR-3	

CONUS Military-Only Site (1)

45	1	CA	SAN CLEMENTE		ARSR-4
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78-FAA CONUS Sites: 20 FPS-Sites; 20 ARSR-1; 16 ARSR-2; 20 ARSR-3; 2 ARSR-60

FAA Sites: Previously JSS Sites (5)

46	1	CA	SAN PEDRO	ARSR-1E	ARSR-3
47	2	NM	SILVER CITY	ARSR-2	
48	3	TX	EL PASO	ARSR-1E	
49	4	TX	ODESSA	ARSR-1E	
50	5	TX	ELLINGTON	ARSR-1E	

FAA CONUS Sites: FPS Sites (22 Current)

51	1	NM	ALBUQUERQUE	FPS-66A	
52	2	LA	ALEXANDRIA	FPS-20A	
53	3	TX	AMARILLO	FPS-67	Mode S
54	4	NV	FALLON	FPS-66A	Mode S

Item No.	Type No.	State	Location	Current Type	Planned Type
55	5	KS	HUTCHINSON	FPS-66	
56	6	PA	OAKDALE	FPS-67	
57	7	NV	LAS VEGAS (Angel Peak)	FPS-20A	Mode S
58	8	VT	ST. ALBANS	FPS-67B	Mode S
59	9	NE	OMAHA	FPS-66	
60	10	SD	GETTYSBURG	FPS-67B	Mode S
61	11	PR	PICO DEL ESTE	FPS-67A	
62	12	AL	HALYVILLE	FPS-67B	ARSR-3
63	13	PA	BENTON	FPS-67	ARSR-3
64	14	IL	HANNA CITY	FPS-67B	
65	15	AR	RUSSELLVILLE	FPS-64A	
66	16	CA	RED BLUFF	FPS-67D	Mode S
67	17	TX	SAN ANTONIO	FPS-66	
68	18	AR	TEXARKANA	FPS-67	
69	19	CA	BORON	FPS-67B	
70	20	MI	COOPERSVILLE	FPS-66A	
71	21	CA	SACRAMENTO	FPS-20	
72	22	OK	OKLAHOMA CITY	FPS-67B	

FAA CONUS Sites: ARSR-1 Sites (18 Current)

73	1	GA	MARIETTA	ARSR-1E	
74	2	OH	CLEVELAND	ARSR-1E	
75	3	IN	INDIANAPOLIS	ARSR-1E	
76	4	AL	MONTGOMERY	ARSR-1E	
77	5	MN	MINNEAPOLIS	ARSR-1E	
78	6	TN	JOELTON (NASHVILLE)	ARSR-1E	
79	7	CO	PARKER	ARSR-1E	Mode S
80	8	NC	BENSON	ARSR-1E	
81	9	NC	MAIDEN (CHARLOTTE)	ARSR-1E	
82	10	IN	LAGRANGE	ARSR-1E	
83	11	NM	MESA RICA	ARSR-1E	Mode S
84	12	OH	LONDON	ARSR-1E	
85	13	MS	BYHALLA (MEMPHIS)	ARSR-1E	
86	14	TX	ROGERS	ARSR-1E	
87	15	WA	SEATTLE	ARSR-1E	
88	16	UT	SALT LAKE CITY	ARSR-1E	ARSR-3 Mode S
89	17	MO	ST. LOUIS	ARSR-1E	
90	18	TX	FT. WORTH	ARSR-1E	

Item No.	Type No.	State	Location	Current Type	Planned Type
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FAA CONUS Sites: ARSR-2 Sites (16 Current)

91	1	CO	TRINIDAD	ARSR-2	Mode S
92	2	NV	BATTLE MOUNTAIN	ARSR-2	Mode S
93	3	KS	GARDEN CITY	ARSR-2	Mode S
94	4	CO	GRAND JUNCTION	ARSR-2	Mode S
95	5	NM	GULLUP(FARMINGTON)	ARSR-2	Mode S
96	6	NE	NORTH PLATTE	ARSR-2	Mode S
97	7	WY	LUSK	ARSR-2	Mode S
98	8	ID	CASCADE (BOISE)	ARSR-2	Mode S
99	9	WI	HORICON	ARSR-2	
100	10	MN	TYLOR	ARSR-2	ARSR-3 Mode S
101	11	KY	LYNCH	ARSR-2	
102	12	WY	LOVELL	ARSR-2	Mode S
103	13	ID	ASHTON	ARSR-2	Mode S
104	14	WY	ROCK SPRINGS	ARSR-2	Mode S
105	15	UT	CEDAR CITY	ARSR-2	Mode S
106	16	KS	OSKALOSSA	ARSR-2	

FAA CONUS Sites: ARSR-3 Sites (10 Current)

107	1	IL	JOLIET	ARSR-3	
108	2	VA	BEDFORD	ARSR-3	
109	3	IA	ARLINGTON	ARSR-3	
110	4	GA	LINCOLNTON	ARSR-3	
111	5	MS	NEWPORT	ARSR-3	
112	6	OR	FOSSIL	ARSR-3	
113	7	AZ	SELIGMAN	ARSR-3	
114	8	VA	BINNS HALL (IVOR)	ARSR-3	
115	9	MO	KIRKSVILLE	ARSR-3	
116	10	PA	CLEARFIELD	ARSR-3	

FAA new CONUS Sites: ARSR-3 Sites (5 Leapfrog)

117	1	OR	BURNS/PINE MTN	NEW	ARSR-3
118	2	TN	SAMBURG	NEW	ARSR-3
119	3	MT	SAND SPRINGS	NEW	ARSR-3
120	4	WI	MEDFORD	NEW	ARSR-3
121	5	OK	ARBUCKLE	NEW	ARSR-3

Item No.	Type No.	State	Location	Current Type	Planned Type
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FAA CONUS Sites: ARSR-60 Sites (2 Current)

122	1	PA	TREVOSE	ARSR-60	
123	2	MA	CUMMINGTON	ARSR-60	

FAA Academy (AERO) Training Site (1)

124	1	OK	OKLAHOMA (AERO)	ARSR-37	ARSR-4
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JSS Sites in Alaska

125	1	AK	KENAI	ARSR-3	
126	2	AK	MURPHY DOME	FPS-117	
127	3	AK	KING SALMON	FPS-117	FAA Listed
128	4	AK	COLD BAY	FPS-117	
129	5	AK	CAPE NEWENHAM	FPS-117	
130	6	AK	CAPE ROMANZOF	FPS-117	
131	7	AK	SPARREVOHN	FPS-117	
132	8	AK	TIN CITY	FPS-117	
133	9	AK	KOTZEBUE	FPS-117	
134	10	AK	POINT LAY	FPS-117	
135	11	AK	POINT BARROW	FPS-117	
136	12	AK	OLIKTOK	FPS-117	
137	13	AK	BARTER ISLAND	FPS-117	
138	14	AK	FT. YUKON	FPS-117	
139	15	AK	INDIAN MTN	FPS-117	
140	16	AK	GALENA	FPS-117	
141	17	AK	TATALINA	FPS-117	
142	18	AK	GALENA	FPS-117	
143	19	AK	ST. PAUL ISLAND	Beacon-	Only Site

JSS Sites in Pacific

144	1	HI	MT. KAALA	ARSR-3	ARSR-4
145	2	HI	MT. KOKEE	FPS-93	TBD
146	3	GUAM	MT. SANTA ROSA	FPS-93	ARSR-4

Military-Only Site in Caribbean

147	1	CUBA	GUANTANAMO BAY		ARSR-4
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